Kakadu

Natural and cultural heritage and management

edited by

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Darwin

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Statement

by the

Kakadu National Park Board of Management

The Board of Management of Kakadu National Park is pleased to endorse the publication of this book. Kakadu is a very important place for us. Kakadu represents a commitment by Aboriginal people to share their land and their cultural heritage with the world.

When you come to Kakadu you will see a place that is very much a living landscape: one that has been occupied and used by Aboriginal people for up to 60,000 years. The Board of Management with its Aboriginal majority is one of the formal manifestations of the continuing management of the landscape by Aboriginal people.

We welcome visitors to Kakadu: we want visitors to come and learn about this very special place.

This book is one way that you can learn about Kakadu. We hope that by learning more you will appreciate the importance of Kakadu for its Aboriginal traditional owners, for us and for the people of Australia.

Brian Baruwei,
Chairperson of the Kakadu Board of Management
Magpie geese in flight (Michael Jensen/AUSCAPE).
Foreword

This is the book that Kakadu, with all its natural beauty and cultural and scientific interest, so richly deserves. By the same token, the book is so well written and academically sound that it deserves a wide readership.

How often does the thoughtful visitor to a world heritage area want to learn more about its natural history, geology or its original occupants – more than a tour guide or local resident can answer? Just to take a few topical examples. How accurate are estimates of the age of rock paintings? What has been the effect of Aboriginal use of fire? What mineral resources are likely to lie within the Park boundaries?

This volume should answer almost all the questions that might be reasonably expected from an intelligent and inquisitive visitor. And for the specialist in any particular field, it provides a fine introduction to each subject and a bibliography for further research. Understanding is greatly helped by clear maps and useful tables.

Although many different experts have contributed to the various chapters, the standard of writing is remarkably even and always as easy to follow as is possible when technical terms have to be used. The editors have also done a fine job with the overall production.

I have read this book from cover to cover and have no hesitation in warmly recommending it to all those with inquiring minds and an interest in Kakadu.

Sir Edward Woodward
Chancellor, University of Melbourne
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Preface

The original concept for this book, a 'Kakadu Resource Book' in its first incarnation, is attributed to Theo Hooy, an employee of the Australian Nature Conservation Agency and a Park Planner. He thought, rightly, that much of the descriptive material that had dominated the earliest plans of management for National Parks in Australia ought to be found elsewhere than in those plans. Plans of management, he argued, should be prescriptive not descriptive.

The first Plan of Management for Kakadu, drawn up in the late 1970s, was very much a descriptive document and reflected the birth of the Park: there was much growing up to do. The succeeding Plans, published in 1986 and 1991, were much less descriptive and progressively more prescriptive. As a result, the plan could no longer be relied on to provide information to an ever more inquisitive and educated public audience.

Much research and inventory had been done in the 1980s and Kakadu accumulated a large, somewhat disjointed and inaccessible collection of consultancy reports and research findings. Although much of this information had been commissioned over the years by the Australian Nature Conservation Agency, there was a great deal of research carried out independently by researchers and scholars from universities (the Northern Territory University (NTU) particularly in later years), the CSIRO (particularly the Tropical Ecosystems Research Centre in Darwin), the Office of the Supervising Scientist (OSS), the Conservation Commission of the Northern Territory (CCNT), The Australian National University's North Australia Research Unit (NARU), the Northern Territory Museum, and other research institutions and government departments.

Theo Hooy convinced me, when we began planning the third Plan of Management for Kakadu in 1990, that it was time to try to compile, in an accessible and readable volume, a precis of information about the
cultural and natural heritage of Kakadu National Park. Thus began the somewhat tortuous path to this current production.

In 1991 Green Ant Publications were given a brief to compile chapters for a resource book on the Park. This they did professionally and effectively, but by then I had moved the goalposts slightly. Some research on visitor expectations that we had commissioned was showing that visitors to Kakadu required 'more information' about the Park. I decided that the publication we were planning should now become more 'saleable' and accessible to the general public.

Given the excellent record of the North Australia Research Unit in producing publications on Northern Australia, I sought to establish with them a joint venture to publish this volume. What is contained herein is the result of that joint venture.

Kakadu is a wonderful place: a landscape of beauty, starkness and drama; of living culture, history and prehistory; a place of abundant wildlife and scarcity; a land of floods, drought and fire. People have shaped its contents as much as the forces of wind, rain, fire and tide have moulded its form. To stand in the South Alligator River valley and know not only of its diversity of plants and animals but to understand its power for its Aboriginal owners and custodians is a privilege that I have had. I hope that this book can give those that want to dig deeper than the television documentary, see further than the bus window, and read more than the park pamphlet, something to take with them or take home.

_Tony Press 1995_

_Executive Director, Directorate for Biocultural Landscapes (North)_

_Australian Nature Conservation Agency_
Acknowledgments

Many people worked on this publication in its various drafts and guises. Of the four editors, Tony Press was one of the original prime movers in this project and never lost his enthusiasm. He has remained one of the movers and shakers of the project, and used to arrive at the North Australia Research Unit (NARU) like a whirlwind bearing new drafts, slides, and names of useful contacts for various production tasks. He also revised the fauna chapter.

David Lea, until June 1994 Executive Director of NARU, supported the concept wholeheartedly and suggested NARU’s involvement in editing and producing the camera-ready copy. In addition to his editorial role, David contributed significantly to the content and choice of the maps. While in Darwin, David was a member of the Kakadu Research Advisory Committee. He has now retired from NARU but continues his interest in the Park and this project.

Ann Webb, also of NARU, co-ordinated editing and production. She enthusiastically undertook the copy editing and preparation for printing, chased referees reports and photographs, supervised the final drafts, harassed the other editors, organised new maps and figures, designed the style and layout, and kept the project on track.

Alistair Graham, the ANCA planning officer responsible for the 1991 Plan of Management for Kakadu National Park, managed the project through its early stages. Chips Mackinolty and Peter Cooke of Green Ant are acknowledged for their initial contribution to this project.

Each chapter has been written by recognised experts. Jeremy Russell-Smith has been heavily committed to and involved in this project from its inception, and wrote a prodigious portion of the book, sometimes in collaboration with others. David Lawrence, commissioned by ANCA and NARU to write a history of the joint management agreement of KNP, helped extensively with ideas and information, and read various
Acknowledgments

drafts, made invaluable comments, and is joint author of chapter 1 on joint management. Sally Brockwell edited, revised and wrote much of the information on Aboriginal heritage; Peter Forrest contributed material to the original manuscript.

Robert Levitus's research was supported by ANCA and the Australian Institute of Aboriginal and Torres Strait Islander Studies. Many past and present residents of the region generously assisted his research. In addition to writing chapter 3 and contributing a section to chapter 2, Robert compiled maps of explorers' routes, with new information about McKinlay supplied by Darwin researcher, Lloyd Browne. Peter Wellings, Manager of Kakadu National Park, was able to find time in his hectic schedule to write the management chapter and advise on many other aspects, including reading an earlier draft of the fire chapter.

John Brock also compiled much of the original 'physical environment' and 'fauna' material. Helen Larson (NT Museum) revised the fish section and Alan Andersen (CSIRO Wildlife Ecology) wrote the section on insects.

Many other recognised experts in the field reviewed chapter drafts. Stewart Needham's (Environment Protection Authority) extensive contributions to a number of topics were particularly helpful. He also devised the generalised geology map which was produced by Gail Hill of the Australian Geographical Survey Organisation Cartographic Services. Darrell Lewis (NARU) provided considerable input on the subject of rock art in Kakadu, and Bert Roberts helped with the explanation of luminescence dating in chapter 2. Colin Woodroffe (Wollongong University), Paul Ryan, Gordon Duff (NTU), John Woinarski (CCNT), Dan Gillespie (Administrator, Christmas Island), Chris Chippindale (Cambridge Museum of Archaeology) and Rhys Jones (ANU), all reviewed various chapter drafts. Dick Braithwaite (CSIRO) read an earlier draft of chapter 7. John Woinarski updated the bird checklist. Paul Horner (NT Museum) checked the taxonomy of reptiles and amphibians; Rod Kennett advised on turtles.

Marion McCabe (CCNT) and Jenny Malone prepared the vegetation map and profile respectively in chapter 5. The Research School of Pacific and Asian Studies Cartographic Unit, ANU, produced the other maps. Paul Ryan prepared figures 4.1–4.5. Mick Alderson and Eddie Hardy
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advised on the revision of the Aboriginal Seasonal Calendar, which is reproduced in this book with their permission. Georgianna Fien (ANCA) and Hilary Sullivan (ANCA) assisted with the calendar. Hilary also provided useful comment on historical and archaeological content.

Nicola Hanssen patiently processed the words of the numerous versions of this production. NARU librarians Colleen Pyne and Sally Roberts checked reference lists. The index was compiled by Max McMaster.

Transparencies and prints were supplied by Jeremy Russell-Smith, Diane Lucas, Greg Miles, Darrell Lewis, Stewart Needham, Garry Lindner, Ian Morris, Martin Armstrong, John Gollings, Ivan Haskovec, Peter Wellings, ANCA, Robert Levitus, Alan Fox, AIATSIS (Tom Cole collection), Michael Storrs, Jean-Paul Ferrero and Michael Jensen of AUSCAPE, Peter Jarver and Carolyn Johns of Wildlight Photo Agency and GE Schmida of Australian Nature Transparencies. Plates 2.12, 2.15, 2.16 and 7.1 are reproduced with the permission of Minnie Gapindi. Plates 3.1 and 3.2 are reproduced with the permission of the Libraries Board of South Australia. Plate 3.7 was supplied by the Northern Territory Library and reproduced courtesy of AGPS.

The concept for the cover design was developed by the North Australia Research Unit and ANCA. Rob King Graphics translated our ideas into the finished design and produced the artwork and separations. Leon and Moira Pericles kindly gave their permission to reproduce Leon’s painting, Nourlangie Rock, on the cover.

And finally, thanks go to Michael Hill (former Deputy Chief Executive Officer) and Peter Bridgewater (Chief Executive Officer) of the Australian Nature Conservation Agency, and to the North Australia Research Unit of The Australian National University, for their support and encouragement of this project.
General map of Kakadu National Park.
1

Kakadu National Park

RECONCILING COMPETING INTERESTS

Tony Press and David Lawrence

1.1 Establishment of Kakadu National Park

The earliest proposal for the establishment of a major national park in the Alligator Rivers region of the Northern Territory was made by the Northern Territory Reserves Board in 1965. Over the next ten years a succession of modified proposals were put forward by interested persons and agencies. These culminated with a formal proposal by the Commonwealth Government to declare under the National Parks and Wildlife Conservation Act 1975 (NPWC Act) a major national park in the region. Stage One of Kakadu National Park was declared in 1979, Stage Two was added in 1984, and Stage Three proclaimed in 1987, with supplementary proclamations in 1989 and 1991. Kakadu National Park was born in controversy and the history of the development of the Park has been one of attempts to reconcile the concurrent and competing interests of conservation, mining and Aboriginal land rights. These issues continue today.
1.2 Aboriginal land rights

In the early 1970s Mr Justice Woodward, commissioned to report on appropriate ways and means to establish Aboriginal land rights in the Northern Territory, addressed the issues of Aboriginal land rights and public reserves and crown land. He suggested that a scheme of Aboriginal title, combined with National Park status and joint management, might prove acceptable to all interests. In his second report, Woodward further developed the concept of Aboriginal land, national parks and joint management in the context of reconciling Aboriginal interests with conservation. In the process he identified a number of principles which needed to be followed if Aboriginal interests were not to be subordinated unreasonably to those of conservation. These principles were: Aboriginal people should be consulted before any schemes for development or management were adopted; Aboriginal people should be well represented on any board or committee responsible for the area in question; other people appointed to a board or committee should have sympathy with, and an understanding of, the relationship of Aboriginal people to their land; Aboriginal interests should not be overruled without reference to some form of arbitration; and development plans should make allowances for any Aboriginal people who may wish to live in the area, particularly those with traditional claims to the land.

1.3 Mining

In the early 1970s significant uranium deposits were discovered in the Alligator Rivers region at Ranger, Jabiluka and Koongarra. In 1975, following receipt of a formal proposal to develop the Ranger deposit, the Commonwealth Government directed that an inquiry under the provisions of the Environment Protection (Impact of Proposals) Act 1974, the Ranger Uranium Environmental Inquiry, be conducted. The recommendations of this inquiry had enormous influence on the nature and development of Kakadu National Park.

In 1976, after the Ranger Uranium Environmental Inquiry had commenced its work, the Aboriginal Land Rights (Northern Territory) Act 1976 was passed by Federal Parliament. This Act granted title to certain areas in the Northern Territory to the traditional Aboriginal owners and
established the processes whereby Aboriginal people could claim title to other areas of unalienated crown land on the basis of traditional ownership of that land, or entitlement by tradition to its use or occupation. The first land claim in the Alligator Rivers region was subsequently dealt with as part of the Ranger Inquiry.

Justice Fox, the Commissioner appointed to head the Inquiry, concluded that the major land use interests in the region should be: the use and occupation of land by Aboriginal people; the establishment of a national park; uranium mining; tourism; and pastoral activities. The Commission's principal recommendations were: grant of title to the area claimed to the Aboriginal claimants; allowance of uranium mining at Ranger and consideration of future uranium mining at Jabiluka and Koongarra; the establishment of a large regional national park to include the proposed Aboriginal land; the resumption of two pastoral leases to enable Aboriginal land claims to be made over the area and the future incorporation of these additional areas into the national park; inclusion in the park of a regional centre, to be established to service the uranium mining operations; prohibition (initially) of tourist developments in the regional centre; and preparation of a plan of management for the park, which should ensure that Aboriginal views were strongly represented.

In submitting the land claims to the Commission the traditional Aboriginal owners had instructed the Northern Land Council, which represented them, to propose that if the claim was successful they would lease the land to the Director of National Parks and Wildlife for the purposes of a national park.

The Commonwealth Government response to the recommendations of the Ranger Uranium Environmental Inquiry was announced in August 1977. Virtually all the recommendations were accepted including those relating to the granting of Aboriginal title and the establishment of a major national park. The Government decided to establish the national park in stages with the first stage to coincide generally with the area proposed as Aboriginal land.

1.4 The town of Jabiru

When Kakadu was declared following the recommendations of the Ranger Inquiry, the township of Jabiru was established in the Park on a lease held
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by the Jabiru Town Development Authority. The land on which Jabiru was established was not granted as Aboriginal land. In keeping with the recommendation of the Ranger Inquiry that Jabiru remain for the time being a closed 'mining town', the first Plan of Management for the Park ruled out tourism developments in the town. Subsequent plans and decisions have seen the gradual development of tourism infrastructure in Jabiru including a hotel and commercial campground. Jabiru has also developed as a small regional centre which services not only tourists and the Park but other communities to the east in Arnhem Land. There is much debate in the community about the future of Jabiru and it is likely that this issue will be prominent in discussions and planning for subsequent Plans of Management for the Park.

1.5 Conservation

The concept of a national park on Aboriginal land was untried in Australia. It required not only amendments to the NPWC and Land Rights Acts, but also the negotiation of appropriate terms and conditions under which the Aboriginal land would be leased to the Director of National Parks and Wildlife to enable it to be declared a national park. A lengthy period of negotiations commenced culminating in the signing of a lease agreement in October 1978. During the same period the necessary amendments to the legislation were prepared and the first stage of Kakadu National Park was proclaimed on 5 April 1979. Since it was proclaimed, or even earlier, the Park has hardly ever been out of the news or the political spotlight. It has generated intense debate over issues such as uranium mining and conservation, mining on Aboriginal land, tourism in World Heritage areas and the relationship between the Northern Territory and the Commonwealth. Overlying all these issues has been the opposition of the Northern Territory Government to Commonwealth Government involvement in the Park and its management by the Australian National Parks and Wildlife Service (now the Australian Nature Conservation Agency – ANCA).

1.6 World Heritage status

The natural and cultural heritage of Kakadu has been recognised by the inscription of the Park on the World Heritage List for both its natural and cultural values. Stage One of Kakadu National Park was inscribed on the
List in 1981 and Stage Two was added in 1987. A consolidated nomination for the whole of Kakadu National Park was accepted by the World Heritage Committee in December 1992.

1.7 Natural history

Kakadu National Park is situated in the wet-dry tropics of northern Australia and represents a broad array of landforms with diverse vegetation associations and related fauna. The Park covers 19 804 square kilometres. In contrast to the great antiquity of underlying geological formations, the riverine and coastal floodplains are modern phenomena. This conjunction of major landforms has produced an ecological and cultural diversity unique to northern Australia.

The Arnhem Land plateau is an area of deeply dissected sandstone with rugged cliffs and spectacular escarpments. It contains relict rainforest vegetation associations as well as essentially arid spinifex-dominated grasslands and wooded savannas. Where the Arnhem Land plateau has eroded in the south of the Park the ancient rocks of the southern hills and basins have been revealed. The lowland plains stretching from the sandstone to the coastal plains contain wooded savannas, forests, rivers, billabongs and fringing vegetation. Although the soils are acidic, shallow and infertile, the plant and animal communities are rich. The four major river systems of Kakadu and the coast have produced extensive freshwater floodplains and backwater swamps as well as estuarine communities, mangroves and mudflats.

1.8 Cultural heritage

The archaeological record suggests that the Alligator Rivers region has sustained human occupation between 40 000 and perhaps as long ago as 60 000 years. During the last 100 000 years, the sea level fluctuated greatly and the northern coast of Australia was sometimes up to 400 kilometres north of its current location. It is most likely that the first Australians arrived to find a much drier landscape than now. At the end of the last glacial period c.15 000 years ago temperatures increased, the sea level rose and the downcut river valleys of northern Australia were flooded. As a result of siltation vast mangrove swamps spread in the river estuaries from about 7000 years ago. Sea levels stabilised around 6000 years ago and further siltation led to the establishment of the freshwater floodplains from about
4000 years ago. Changes in sea level and the creation of estuarine and freshwater ecosystems are all events which have been recorded directly or indirectly through the magnificent rock art of the Arnhem Land escarpment and plateau and reflected in the record of material culture.

The Aboriginal people made good use of the abundant natural resources and the region supported substantial populations. When the first Europeans came to the area it is estimated that the population of the Kakadu region was about 2000. The subsequent decline in the Aboriginal population through introduced diseases and social dislocation occurred from the end of the nineteenth century but continued into the present century.

The Alligator Rivers region was marginal to the economy of the Northern Territory in its early development. Asian water buffalo had been introduced through the Cobourg Peninsula in the 1840s and had moved south into the freshwater swamps. Buffalo hunting sustained a subsistence economy in the region which continued until the 1950s. Men hunted the animals on foot and on horse across the northern floodplains and women salted and cleaned the heavy hides for export to markets. Aboriginal people from the Alligator Rivers region have a long and proud history of involvement in the buffalo industry.

The Aboriginal traditional owners of Kakadu National Park are active participants in the management of the Park. In 1979 probably less than 100 Aboriginal people were residing in the area of Kakadu National Park. Since that time the numbers have increased markedly and in 1992 it is estimated that some 300 Aboriginal people reside in the Park. Many of these Aboriginal residents are traditional owners and others have recognised social and historical affiliation to the area. Permanent Aboriginal living areas are established at ten or more locations throughout the Park and these are serviced and maintained by the Aboriginal-owned Gagudju Association. The Gagudju Association also operates a variety of commercial enterprises throughout the Park, including the Gagudju Crocodile Hotel in Jabiru, the Gagudju Lodge Coinda Hotel-Motel and the Yellow Water boat tours. A second Aboriginal association, the Djabulukgu Association, owns and operates the Marrawuddi Gallery at the Bowali Visitor Centre and the East Alligator River Cruise. The Gagudju Association runs the commercial operations of the Warradjan Cultural Centre, constructed by ANCA and opened in 1995.
1.9 Joint management arrangements

The involvement and participation of the Aboriginal community in the joint management of Kakadu National Park is assured through legislation, conditions of lease, the plan of management and other management arrangements such as the establishment of a Board of Management with a majority of Aboriginal members, and through day-to-day management operations.

1.10 Legislation

The two most important pieces of legislation governing the operation of Kakadu National Park are the Aboriginal Land Rights (Northern Territory) Act 1976 and the National Parks and Wildlife Conservation Act 1975. Both required substantial and complementary amendment in 1978 so that the Commonwealth's decisions on Kakadu National Park, following the recommendations of the Ranger Inquiry, could be implemented.

The land rights legislation provides for unalienated land in the Northern Territory to be claimed by traditional Aboriginal owners. It establishes procedures for the claim to be argued before an Aboriginal Land Commissioner and for title to the land to be granted to an Aboriginal Land Trust. The act also established a number of Land Councils whose functions are: to ascertain and express Aboriginal views on land management; to protect the interests of traditional owners of land; to consult traditional owners with regard to proposals for use of their land; to negotiate on behalf of the traditional owners and to assist Aboriginal people claiming land to pursue their claims. Currently there are four Land Councils in the Northern Territory and Kakadu National Park lies within the area of responsibility of the Northern Land Council (NLC). The NLC has played a major role, over the years, in the establishment and further development of joint management arrangements for the Park.

The National Parks and Wildlife Conservation Act 1975 established both the statutory office of Director of National Parks and Wildlife and the Australian National Parks and Wildlife Service. It also provided for Aboriginal land in the Alligator Rivers region, which was leased to the Director, to be declared national park. It required that a plan of management be prepared for a park as soon as feasible after declaration.
Further amendments to the NPWC Act in 1979, 1985 and 1987 provided the legal basis for the further development of the joint management arrangements.

Most specifically the NPWC Act provides for the establishment of Boards of Management for parks established on Aboriginal land. These Boards have a majority of Aboriginal representatives. In managing the parks, these Boards have functions and powers equal to that of the Director of National Parks and Wildlife: they prepare, in conjunction with the Director, plans of management for the parks; they make decisions on management consistent with the Plan of Management; they monitor management of the parks; and, in conjunction with the Director, advise the Minister on future developments in the parks.

1.11 Conditions of lease

The original lease agreement in 1978 setting out the terms and conditions applying to the lease of Aboriginal land to the Director was the result of negotiations between the NLC and the Director. The agreement was primarily concerned to ensure an appropriate level of involvement in managing the Park by the traditional owners. It required the Director to consult, on all matters affecting Aboriginal people, with officers of the NLC who would ascertain and represent the views of the traditional owners.

Under the terms of the agreement the Director accepted obligations to train local Aboriginal people in skills necessary to enable them to assist in management of the Park; to employ as many traditional Aboriginal owners as practicable under conditions that recognise their special needs and their culture; to promote among non-Aboriginal people a knowledge and understanding of Aboriginal traditions, culture and languages; to engage Aboriginal people in Park interpretation programs; to consult with the NLC in preparing a plan of management for the Park to ascertain the wishes and opinions of the traditional owners; and to have due regard to the needs of traditional owners in their use of, and movement throughout, the Park.

The original lease was renewed in 1991. Over time it had became apparent that the original lease needed to be re-negotiated to take account of the evolving situations in the Park. Of particular significance were the
incorporation of the Gagudju, Djabulukgu and Jawoyn Associations whose members were the traditional owners of a major part of Kakadu National Park, the huge expansion in the size of the Park, the establishment of a Board of Management with an Aboriginal majority, the charging of park use fees and increasing tourism in the region.

These new lease arrangements reflected a maturation of the relationship between the management agency and the Aboriginal traditional owners. The financial provisions now provide for an indexed annual rental and a percentage of income derived from entry fees. The lease also requires that the Park is managed to the highest world standards, and reflects a commitment and determination of the Aboriginal traditional owners that the natural and cultural heritage of the Park is maintained. The lease provides for employment and training of Aboriginal people in all areas of park management. Further provision of the new lease arrangements, which required much negotiation, involve the issue of detriment. The new arrangements now provide for termination of the lease if issues of detriment to the Aboriginal traditional owners cannot be resolved.

The terms and conditions of the Kakadu lease have evolved from the experiences of lease arrangements that other conservation agencies have entered into with Aboriginal traditional owners. After the original Kakadu lease the Aboriginal traditional owners of Gurig and Nitmiluk (Katherine Gorge) National Parks negotiated leases with the Northern Territory Government, and the traditional owners of Uluru-Kata Tjuta National Park negotiated a lease with the Director of National Parks and Wildlife.

1.12 Management arrangements

The three major pillars of the management of the Park are the Board of Management, the Plan of Management and day-to-day liaison. The Board of Management was established in 1989. The Board in Kakadu National Park comprises 10 Aboriginal nominees of the Aboriginal traditional owners, and four others: the Director of National Parks and Wildlife, the regional ANCA executive, an ecologist, and a person with expertise in tourism (see Appendix I). The Aboriginal representation on the Board reflects the geographic spread of Aboriginal people in the region as well as the major language groupings.
PLATE 1.1 Signing the Kakadu National Park lease agreement, 1978. L–R: Mick Alderson, Murumburr traditional owner; Ian Viner, Minister for Aboriginal Affairs; Derek Ovington, Director ANPWS (Alan Fox).

PLATE 1.2 Kakadu National Park Aboriginal Consultative Committee meeting to discuss the Third Plan of Management, 1990 (Peter Wellings/ANCA).
PLATE 1.3  Park Manager having discussions with members of the Board of Management (RW Braithwaite/CSIRO).

PLATE 1.4  Bill Neidjie, senior traditional owner and long-time employee of ANCA, at work in the Park (Greg Miles/ANCA).
PLATE 1.5 Bawali Visitor Centre, Kakadu National Park (John Gollings).

PLATE 1.6 Warradjian Cultural Centre, Kakadu National Park (Greg Miles/ANCA).
The first task taken on by the Kakadu Board was the writing of the third Plan of Management. As part of the process of developing this plan an Aboriginal Consultative Committee was established. The Consultative Committee consisted of representatives of all Aboriginal communities and groups in the Park. Its task was to consult and advise on all aspects of the Plan of Management. Park staff and the Board of Management were required to provide comments to the Consultative Committee. The Board meeting which considered the final amendments to the draft Plan was provided with an extensive brief which comprised proposed amendments to the Plan from public submissions, as well as the comments and the proposed amendments of the Consultative Committee.

The role of the Board in the process of drawing up the Plan was both as adviser to the drafters and final arbiter of the contents. An important management principle, which can be traced back to the recommendations of the Ranger Inquiry, is that the Park is managed as if it were Aboriginal land, even if the formal land claim process has been unsuccessful or still under consideration. The Third Plan of Management came into effect after approval by both Houses of Parliament in April 1992.

The other major role of the Board is to make decisions (consistent with the Plan) regarding the management of the Park. The Board has executed this duty by meeting four times a year since its inception.

While the Board provides the formal and ongoing expression of joint management, the success of joint management lies in the opportunities provided for direct involvement of Aboriginal people in day-to-day decision making and liaison. The maintenance of successful joint management arrangements into the future will also depend not only on the statutory and legal arrangements but also on the informal liaison arrangements. These informal arrangements include among other things local meetings to discuss specific issues; the employment of senior traditional owners as cultural advisers; day-to-day working contact with the traditional owners; and the employment of increasing numbers of young Aboriginal people in all areas of Park management.

1.13 Successful joint management

There are some fundamental requirements of effective joint management arrangements if these are to be beneficial to both the
community and to nature conservation: Aboriginal people must be empowered, through legal ownership of some, or all, of the land involved, and have the principal role in the decision-making process, most importantly through a majority on the Board of Management. It is also important that Aboriginal people be involved through direct employment, extensive consultation and provision of advice on day-to-day management issues. Joint management needs to be clearly understood. It is crucial that each party to the agreement fully understands the expectations of joint management. The expectations of each party need not necessarily be identical but each party must understand, appreciate and, importantly, respect the other's viewpoint. It is essential that the management agency be fully committed to the process of joint management. This commitment must come from the very top of the agency and from the most senior people in the community. Particular care must be taken to select the right people for employment both within the management agency and in the National Park. Special qualities are required in the non-Aboriginal staff employed to work in such a cross-cultural environment and cultural awareness training is important.

1.14 Postscript

The Commonwealth Parliament recently passed the Native Title Act 1993. This complex piece of legislation will make fundamental changes to the way in which land ownership is perceived in Australia. New concepts of national parks, or the control and management of national parks, will emerge from changing attitudes and the renegotiation of land titles. It may be that an expansion of joint management arrangements will be seen in Australia. It is hoped that the successes and failures of Kakadu National Park will act as a guide for these developments.

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Aboriginal heritage

Sally Brockwell, Robert Levitus, Jeremy Russell-Smith and Peter Forrest

Kakadu National Park is culturally significant for all Australians. It is a World Heritage area containing some of the oldest and best preserved archaeological sites in Australia, including extensive galleries of some of the world’s finest rock art (Plate 2.1). These sites can reveal much information concerning the arrival of the first people on the Australian continent and their economic and social adaptations to the changing northern environment over thousands of years. Kakadu is particularly significant for the Aboriginal people who live there. Not only are they the inheritors of one of the longest cultural traditions in the world, but they still attach strong cultural significance to the meanings they perceive in the natural landscape and the social structures through which they maintain their bonds with the land.

The Aboriginal heritage of Kakadu is represented in three kinds of places: archaeological sites containing material cultural remains, which include both open sites (Plate 2.2) and occupation deposits; archaeological sites containing art (Plate 2.1); and sacred sites. As will be clear from what follows, these categories are not clearly separable in terms of location and significance, and there is considerable overlap between the three classes of site.
Before discussing archaeological sites in Kakadu it may be useful to define some terms which are commonly used by archaeologists, and to explain briefly the different techniques that have been used to date sites in Kakadu.

The Pleistocene Epoch is a geochronological division of time which began c. 1.8 million years ago and consisted of a number of glacial and inter-glacial periods. The Holocene Epoch is the period which followed the Pleistocene Epoch at the end of the last ice age. The Holocene is characterised by warmer climates and little or no glacial ice. It is generally agreed this period began about 10,000 years ago and continues until the present (Bahn 1992, 215, 400).

The two dating techniques discussed below are radiocarbon or C14 dating, and luminescence dating. Carbon is present in organic materials, such as bone, wood, plants and shells, which are often found in archaeological deposits. As C14, a component of carbon, decays at a radioactively fixed rate which can be measured, it is possible to date organic materials. Only small samples are required and the method is reasonably reliable up to 50,000 years (Bahn 1992, 422).

Luminescence dating is a method of dating sediments deposited within the last half million years or so. It can be used to extract dates from a wide variety of crystalline materials, such as quartz, feldspar and zircon. Electrons are trapped at defects within mineral grains as a result of energy absorbed from the decay of radioactive elements in soil and rock, and accumulate at a steady rate. Once exposed to sunlight or heat the electrons are released in a form of light called luminescence and the luminescence ‘clock’ is set to zero. When reburied the minerals begin to store energy once more. In the laboratory, luminescence from a sediment sample can be released by artificial exposure to heat (thermoluminescence, TL) or light (optically-stimulated luminescence, OSL). The longer a sample has been buried, the more TL or OSL is released. The time that has elapsed since the sample was last exposed to sunlight or heat can then be calculated by measuring the amount of luminescence emitted and the background radioactivity of the sample site. Overseas, this method of dating has been applied mainly to artefacts which have been heated, such as pottery, flint or hearth stones. In Kakadu, because of the rarity of these artefacts in archaeological deposits, this technique has been used on quartz contained in soils. Quartz is useful because it occurs everywhere and has an age limit of 200,000 to 300,000 years which covers the period of

2.1 Archaeological deposits and open sites

Archaeological material cultural resources are numerous in Kakadu and include occupation deposits in rockshelters, quarries where stone raw material was extracted and processed, human burial sites, stone or bone arrangements, surface scatters of stone, and earth and shell mounds (ANPWS 1991a, 53). These resources are found in rockshelters and open sites throughout the valleys and outliers of the Arnhem Land plateau, in rockshelters in the sandstone country on top of the escarpment, and in open sites scattered across the coastal plains (Plate 2.2). Aboriginal people favoured rockshelters as sites for camping, shade and protection from the wet season rains. Archaeological debris left over from the activities of these people, such as stone, bone, shell and plant remains, has been preserved within deposits which have built up on the floors of the shelters. Excavation of these sites has established sequences of occupation which have been dated and analysed. They provide important details of hunter-gatherer lifestlyes over many thousands of years (Allen & Barton 1989; ANPWS 1991b, 15; Kamminga & Allen 1973; Jones 1985b; Schrire 1982).

Climatic change

To put the archaeological record in context we need to consider some of the climatic and landscape changes that have occurred in the past in northern Australia.

Little is known of the climate before about 20,000 years ago. However, from that time until about 13,000 years ago, it is known that it was drier than at present. The range of flora and fauna then available is now restricted to drier areas south of Kakadu (ANPWS 1991b, 16; Bowler et al. 1976; Hiscock & Kershaw 1992, 47; Jones 1988, 9; Jones & Bowler 1980, 11, 14).

With a rise in global temperatures about 15,000 years ago continental ice sheets began to melt, causing a subsequent rise in sea level which continued throughout the end of the Pleistocene until the mid Holocene about 6000 years ago. Increased rainfall from about 10,000 years ago made the environment a more comfortable place to live. The vegetation consisted
mainly of woodland and open forest similar to today and the wetter conditions encouraged the spread of rainforest (Allen & Barton 1989, 10).

The rising sea level caused flooding of existing river valleys in Kakadu. On the South Alligator River this event has been dated to between 8500 and 8000 years ago. The floodplains gradually silted up leading to the development of vast mangrove swamps about 7000 years ago. These in turn were replaced by saline mudflats about 3000 years ago.

More recently, processes of siltation and levee formation restricted the incursion of salt-water tides and allowed the formation of freshwater swamps that are refilled each year by wet season rains. This change has been dated to about 4000 years ago on the lower South Alligator River floodplains and to about 1500 years ago on the middle South Alligator River and Magela Creek floodplains (Chappell 1988; Clark & Guppy 1988; Clark et al. 1992; Hope et al. 1985; Woodroffe 1988; Woodroffe et al. 1985a, 1985b, 1986).

Arrival of Aboriginal people in Australia

Evidence from long occupation sequences in the rockshelter sites of Kakadu has provided the opportunity to investigate the arrival of the first people in northern Australia. It is widely supposed that the first landings were probably made from what is now the Indonesian archipelago late in the Pleistocene period. Between about 120 000 and 6000 years ago, the sea level lay below its present level. During this time there were a number of fluctuations, the lowest points being at around 110 000, 90 000, 70 000 and 19 000 years ago. During these periods mainland Australia and New Guinea formed one continent and were separated from the Indonesian island chain by only 60–100 km of water. It is possible that sea crossings were made at these times (Allen & Barton 1989, 5; ANPWS 1991b, 15–16; Chappell 1993, 43; Jones & Bowler 1980, 11, 12; Mulvaney 1975, 130; White & O’Connell 1982, 45–6).

Alternatively, Chappell (1993) has argued that early watercraft may have been introduced during periods of rising sea levels which favour coral reef expansion and the development of resource rich mangrove and fresh backwater swamps in river estuaries. He proposed that, as a result of this innovation, sea crossings may have been made at the time of rising sea levels, especially between places where distance was little affected by sea level rise (Chappell 1993, 46–47). Possible times for sea crossings would
therefore be at or shortly before high sea levels which occurred around 100 000, 80 000 and 60 000 years ago. On present archaeological evidence (see below) he favours c.60 000 years as a likely date (Chappell 1993, 47).

Since the 1960s a number of rockshelter sites have been excavated in Kakadu. Radiocarbon dating from northern sites, such as Nawamoyyn, Malangangerr and Malakunanja II, and southern sites such as Nauwalabila I, established human occupation in the region to at least 20 000 to 25 000 years ago (Allen & Barton 1989; ANPWS 1991b, 16; Jones & Johnson 1985a; Kamminga & Allen 1973; Schrire 1982).

At some sites, artefacts were present below the radiocarbon dated levels in the deposits, suggesting even earlier human occupation. Recent thermoluminescence dates of sediment samples from the lowest occupied levels at Malakunanja II and Malangangerr have been used to infer that people may have been present in Kakadu between 50 000 and 60 000 years ago. Optically-stimulated luminescence dating of Nauwalabila I has been used to suggest initial occupation of the site between 53 000 and 60 000 years ago. These are the oldest dates so far proposed for Aboriginal occupation in Australia (ANPWS 1991b, 16; Roberts & Jones 1994; Roberts et al. 1990c, 1993). However the validity of the luminescence dates from these sites are currently being debated (Allen 1994; Allen & Holdaway 1995; Bowdler 1990, 1991; Hiscock 1990; Roberts et al. 1990a, 1990b, 1994).

**Occupation sequences**

Stone artefacts found in the lower levels of the Kakadu rockshelters show that the early inhabitants had a relatively sophisticated technology. They manufactured flaked stone artefacts, used grindstones, ground ochre pieces, and hafted edge-ground axes at least 20 000 years ago, one of the earliest examples of edge-grinding technology in the world. Grindstones, ochre pieces and stone axes continued to be used at sites throughout the late Pleistocene and Holocene periods until the recent past (Allen & Barton 1989; ANPWS 1991b, 17; Flood 1990, 85; Jones & Bowler 1980, 15; Jones & Johnson 1985a; Kamminga & Allen 1973; Meehan et al. 1985; Schrire 1982; Spencer 1914, 125, 151, 244–6, 248, 353–5, 429, 431; 1928, 774, 844–5).

The lack of organic preservation in sites older than 7000 years means that it is difficult to define economic activities before that time. However
the arid conditions between 25 000 and 10 000 years ago suggest that the economy was mainly land based, with people hunting animals such as macropods and emus. The region as a whole probably supported a relatively small human population. People would have been obliged to range over large areas to obtain sufficient food (ANPWS 1991b, 16; Jones & Bowler 1980, 14; Lewis 1988, 81–85).

The post-Pleistocene rise in sea level, the subsequent flooding of the downcut river valleys of the north from about 8500 years, and the spread of mangrove forests from about 7000 years, would have had dramatic effects on local people. Populations living along the prior coasts and plains to the north of present day Kakadu would have been forced to relocate inland as the seas rose. The flooding of the river valleys would have reduced the amount of land available especially in northern Kakadu where the floodplains of the East Alligator River and Magela Creek meet the barrier of the Arnhem Land escarpment (ANPWS 1991b, 17; Jones & Bowler 1980, 14). However, the increase in rainfall and the extra resources available from mangrove swamps and rainforests meant that the environment could support a larger population. Increased activity at the rockshelter sites suggests that there were in fact more people living in the region from 6000 years ago onwards (Brockwell 1989, 226–7, 233; Jones 1985a, 293). Middens (accumulations of food refuse, usually including a large proportion of shellfish remains) began to build up in the rockshelter sites bordering the northern floodplains from 7000 years ago and show that people took advantage of the new food resources (Allen & Barton 1989; ANPWS 1991b, 17; Kamminga & Allen 1973; Schrire 1982).

From about 5000 years ago, there were a number of changes and additions to previous stone technology, which included finely worked small stone points and steep-edged chisels. Organic preservation in deposits younger than 7000 years is good, and tools made from bone, wood and shell have also been found among the archaeological remains of this period (Allen & Barton 1989; ANPWS 1991b, 18; Jones & Johnson 1985a, 1985b; Kamminga & Allen 1973; Schrire 1982).

Freshwater wetlands developed on the floodplains of the Alligator Rivers region between 4000 and 1500 years ago. From this period until the recent past, there is archaeological evidence of habitation at open sites on the floodplains which contain middens and extensive surface

Evidence from open sites on the South Alligator River and increased activity at some rockshelter sites suggest that from 1000 years ago there may have been a dramatic increase in human occupation of the region based on the rich resources of the newly formed freshwater floodplains. New stone artefacts in the form of large points (‘leilira blades’) and use-polished flakes (probably used in the processing of one of the plants from the wetlands) also appear in the upper levels of the rockshelters and the open sites of this period (Allen & Barton 1989; ANPWS 1991b, 17–18; Brockwell 1989; Jones 1985a; Jones & Johnson 1985b; Kamminga & Allen 1973; Meehan et al. 1985; Schrire 1982).

Investigations at three sites within Kakadu (Paribari, Anbangbang I and Djuwarr I) have revealed many fragile items of material culture, such as wooden and fibre artefacts, which are not often preserved in Australian archaeological deposits. The sites also contain food remains of plants and bone, as well as artefacts made from bone and shell. The preservation of these items has allowed a detailed reconstruction to be made of Aboriginal material culture and technology during the freshwater period over the last thousand years (ANPWS 1991b, 86; Clarke 1985, 1989; Jones & Johnson 1985b; Schrire 1982).

Many of the Kakadu sites continued to be occupied throughout the period of contact with other cultures from 300 years ago until recently. Items of metal and glass have been recovered from the upper levels and surface dust of both rockshelter and open sites. Sites, especially those on the freshwater floodplains, continue to be used today by Aboriginal people for hunting and fishing, and the gathering of plants for food and the manufacture of traditional items of material culture (Brockwell 1989; Jones & Johnson 1985a, 1985b; Meehan et al. 1985) (see below).

2.2 Art sites

The art and its significance

Kakadu National Park contains the largest and best known complex of rock art in Australia and is one of the most important rock art regions of
the world. Approximately 5000 rock art sites have been recorded in Kakadu so far and it is thought that there are at least 10 000 sites in total. Many of these sites contain large numbers of paintings. Most of the shelters containing art are found on the Arnhem Land plateau, along the edges of the escarpment, in the gorges, and in outliers and residuals on the plains (Plate 2.1) (ANPWS 1991b, 25; Chaloupka 1993). George Chaloupka has spent many years recording and analysing the art of Kakadu, and makes the following assessment:

The rock paintings of this region ... represent the world's longest continuing tradition of this art form, and consisting from its very beginning of naturalistic and narrative images, it forms the longest historical record of any group of people. It is a record of encyclopaedic magnitude (Chaloupka 1983, 4–5).

The art at the majority of sites consists of paintings, but there are some rock engravings and designs in wax. There are three kinds of engraving: pecked motifs depicting subjects such as bird, macropod and human tracks; pounded motifs of groups of circular pits; and abraded grooves. Images or patterns made from beeswax are found throughout Kakadu, but the majority of known engraving sites are in the southern region and are rare in the north (ANPWS 1991b, 22, 29–30; Chaloupka 1993).

Pigments used in the paintings were produced by grinding up iron-stained clays and other naturally occurring minerals and mixing them with water. The most common colours are yellow/orange (limonite, geothite and iron-stained clays), red (haematite and iron-stained clays), white (kaolinite and huntite) and black (manganese and charcoal). These pigments were used in various ways. Some was applied with brushes made from chewed twigs, feathers or hair. Intricate cross-hatching was executed with specially shaped pandanus leaves, and paint was applied to large areas by hand. Occasionally paint was sprayed from the mouth onto the rock face. This method was also used when making stencils of hands (Plate 2.3) or of objects such as boomerangs (ANPWS 1991b, 22; Chaloupka 1993, 83–6; Clarke & North 1991).

Aboriginal people hold their own views about the nature of rock art and its origins. The older art styles are often said to have been painted by spirit people rather than humans. These spirits are said to have been the original people of the area, who taught the ancestors of the Aborigines
how to paint, and who still inhabit western Arnhem Land in spirit form. These paintings form a continuing link with traditional beliefs about the formation of the landscape and the emergence of Aboriginal culture. More recent rock art is a repository of traditional knowledge. Subjects depicted include economically important animals, totemic kin, ancestral heroes and other Dreamtime beings, and the art still plays an important role in the cultural life of Aboriginal people today. Paintings of ancestral beings, malevolent spirits and dangerous creatures are thought by Aboriginal people to have depicted themselves on the rock face and are regarded as their actual bodies rather than mere painted images. It was considered that by renewing the paintings of Dreamtime beings an artist could reinforce or release the sacred powers of the being represented. Rock engravings are also thought to belong to the ancestral past. So-called 'rubbish paintings' are crude motifs executed by unskilled people and belong to the recent past (ANPWS 1991b, 22, 25; Brandl 1973, 1; Chaloupka 1993, 23, 87; Mountford 1956; Taçon 1989a, 236–7, 1992b).

Ethnographic information suggests that although some individuals were recognised as particularly skilled there were no professional artists, and the art itself was more important than the identity of the individual artist. Painting was an essential accompaniment to ritual and ceremony and the best artists were those who had great knowledge of law, myths, rituals and ceremonies. People also painted to teach children, for artistic expression, to record events such as a successful hunt, and to illustrate stories. Some rock paintings were produced by people who are still remembered within the Aboriginal community today (Plate 2.4) (ANPWS 1991b, 22, 87; Chaloupka 1993, 23, 25, 238–41; Haskovec & Sullivan 1989, 61, 71; Taçon 1992a; 1992b).

Art sites in Kakadu also document the changes that occurred to this Aboriginal hunter-gatherer society as it came into contact with other cultures. From the seventeenth century onwards Aboriginal people were visited by Macassan fishermen, European navigators and explorers, and later Chinese miners and European buffalo hunters, missionaries and settlers. As a result of these outside influences, artists began to depict such items such as guns, ships and horses (Plate 2.3) (ANPWS 1991b, 88; Chaloupka 1985, 1994; Taçon 1993). It has been suggested that the disruption of Aboriginal association with traditional lands caused by
European incursions led to increasing use of the alternative art form of bark painting (ANPWS 1991b, 29; Chaloupka 1984, 1985).

More recently, with the return to traditional lands through the ‘outstation movement’ and the empowerment of Aboriginal people through land rights legislation, traditional artistic systems have once more become prominent. Many people have become skilled artists and use traditional motifs from rockshelters as inspiration, although these days they paint on bark and modern media such as canvas and paper. Paintings produced today by artists from Oenpelli and other art centres are much sought after on the world art market (ANPWS 1991b, 25; Chaloupka 1993, 215).

**Age and chronology**

Kakadu rock paintings are the product of a continuing artistic tradition reaching back many thousands of years. Although the paintings themselves cannot be directly dated, three other kinds of evidence give an indication of their antiquity. First, pieces of ochre with ground facets occur throughout archaeological deposits in the region. Ochre was present in the lowest excavated levels at Malangangerr, Nawamoyn and Malakunanja II which have been radiocarbon dated to between 18,000 and 22,000 years (Kamminga & Allen 1973; Schrire 1982). At Malakunanja II, recent thermoluminescence dating revealed that the lowest occupied levels which contain ochre may be as old as between 50,000 and 60,000 years (Roberts & Jones 1994; Roberts et al. 1990c). Ochre has also been found in levels at Nauwalabila I which have been dated by the optically-stimulated luminescence method to about 50,000 years (Jones & Johnson 1985a, 219; Roberts & Jones 1994; Roberts et al. 1993). As mentioned above, the validity of these luminescence dates is still being debated. Nevertheless, the evidence indicates that people in the Kakadu region were expressing themselves artistically at least 20,000 years ago and perhaps as long ago as 60,000 years. Whether they used this ochre for rock painting and whether any such paintings survive is unknown, although the large quantities of ochre present in the rockshelters suggest that it was used to decorate the walls (ANPWS 1991b, 25, 85; Chaloupka 1993, 81–2).

Second, different styles of paintings contain different subject matter. These styles are often superimposed over one another, forming a sequence that
reflects environmental changes in climate, flora and fauna; and changes in cultural practices such as economic activities, technology, material culture, religion and ideology. The subjects of the paintings and the changing styles can be related to known and dated climatic and geomorphological events and to evidence obtained from examining archaeological occupation sites in the region (ANPWS 1991b, 25).

Third, radiocarbon dating of mineral ‘skins’ which cover some of the art has shown that some of them may be as old as 9000 years (Watchman 1987). Watchman (1991) argued that the mineralogy of some of the skins suggests that they were formed under climatic conditions different from those of the present, and probably of the immediate post-glacial period (10 000 to 8000 years ago) when the climate was changing from cooler and dryer to warmer and wetter (ANPWS 1991b, 25). However, there are problems with this method as the relationship between the rock art pigment and the layers within the mineral skins has not yet been established, and there is uncertainty regarding the origin and geochemical history of the carbon (Rosenfeld 1993, 74).

Mountford (1956) was the first researcher to make known the riches of Arnhem Land rock art and to recognise the superimposition of the older style red monochrome art by the polychrome ‘X-ray’ art of more recent times. Since Mountford’s pioneering work there have been a number of other studies aimed at classifying and dating the paintings (cf. Brandl 1973; Chaloupka 1977, 1983, 1984, 1985, 1993; Chippindale & Taçon 1993; Haskovec 1992; Jelínek 1989; Lewis 1988; Taçon 1989a, 1989b; 1992b; Taçon & Chippindale 1994). Brandl (1973) was the first researcher to attempt to produce a detailed chronology of Arnhem Land rock art from the earliest times to the recent past. More recently, comprehensive chronologies have been developed by Chaloupka (1984, 1985, 1993) and Lewis (1988). Summaries of their work are presented below.

Chaloupka (1985, 270–1; 1993) defined various art styles and grouped them into art periods and phases. He subsequently developed his chronology by relating the subject matter of the art periods to known climatological, geomorphological, archaeological, historical, zoological and botanical data, as well as evidence of weathering, chemical changes in the rock surfaces and pigments, and the order in which paintings are apparently superimposed at particular sites (ANPWS 1991b, 25–6).
According to Chaloupka, the key to major stylistic changes lies in significant environmental changes, particularly sea level fluctuations, experienced in the region during the late Pleistocene and early Holocene (ANPWS 1991b, 26). On this basis he proposed four main chronological periods for the classification of rock art in Kakadu; the 'Pre-Estuarine Period' (before 8000 years ago); the 'Estuarine Period' (from 8000 to 1500 years ago); the 'Freshwater Period' (from 1500 years ago); and the 'Contact Period' since Macassan and European contact (from 300 years ago) (Chaloupka 1984, 1985, 1993).

Chaloupka (1983; 1985, 271-2; 1993, 79-82) argued that the early art styles of the Pre-Estuarine Period date from at least 20,000 years ago and may be as old as 50,000 years, based on the luminescence dates from the archaeological deposits. In support of his claim he pointed to hunting weapons such as boomerangs which could have been effectively used only in the grasslands and low woodlands that predominated in Kakadu at that time. He also pointed to depictions of animals, such as the New Guinea species of long-beaked echidna (Zaglossus sp.) and a large browsing marsupial with a short tapir-like trunk (Palorchestes), both of which have been extinct in Australia since the late Pleistocene period, 18,000 to 15,000 years ago (ANPWS 1991b, 85; Chaloupka 1985, 272-4; 1993, 99-100; Murray & Chaloupka 1984). However, some of Chaloupka's extinct faunal identifications have since been questioned (Lewis 1986).

The Pre-Estuarine Period contained a number of different styles (Chaloupka 1985, 271-6; 1993, 91-151). The earliest of these consisted of prints of hands, grass and other objects. These were followed by paintings of naturalistic figures, including macropods and extinct fauna; dynamic figures (mainly human but also some animal figures in an animated style) (Plates 2.5 & 2.9); post-dynamic figures (a more stylised version) (Plate 2.10); simple figures with boomerangs (stick-like figures); Mountford figures (human figures, many elongated); and yam figures (yam images transposed into humans and animals) (Plate 2.6). Weapons such as spears and spearthrowers were also clearly illustrated in the art (Plates 2.5 & 2.9). Some of these weapons were still being made in the region in historic times (Chaloupka 1993, 146-8). Although Chaloupka (1993, 81, 91) speculated that the Pre-Estuarine Period could be as old as 50,000 years, he considered that the main body of art from this period dated from 20,000 years to 8000 years
ago (Chaloupka 1993, 89). The presence of various macropods and human figures with boomerangs as common subjects in the rock art during much of the Pre-Estuarine Period suggested that the vegetation was largely open savanna at that time. The stylistic similarity of rock art over large areas of Kakadu and the Arnhem Land escarpment implied that Aboriginal groups at this time ranged over larger territories and were more closely related culturally than they are today, sharing similar languages and belief systems (ANPWS 1991b, 16–17).

Chaloupka (1985, 276; 1993, 138–43) argued that the changing art of the late Pre-Estuarine Period reflected a changing world for the Aboriginal people. At this time the ‘yam figure’ style (Plate 2.6) became prominent, possibly indicating a wetter environment which allowed for the widespread growth of yams, a significant carbohydrate food source. Representations of the Rainbow Snake, which is still important in present day Aboriginal culture, appeared for the first time as part of this style. Chaloupka pointed out that the yam style, which he estimated to be at least 8000 years old, marked a change from naturalism and schematisation to symbolism in the art. He speculated that this change reflected the introduction of new mythologies into the Kakadu region following the rise in sea level which would have forced coastal peoples to retreat inland. Today the Rainbow Snake is often associated with rain and floods, and in coastal areas there are myths about the serpent which rises from the sea and eats people.

By relating subject matter to evolutionary changes in floodplain conditions from 8000 years ago, and the consequent changes in the nature of the resource base, Chaloupka (1984, 42–47; 1985, 277; 1993, 153–83) defined an ‘Estuarine Period’, characterised by the appearance of animals, particularly fish, which flourished in the region with the emergence of estuarine conditions. Representations of macropods and emus became less common. Depictions of hunters with a range of weapons and tool kits documented the changes in technology which took place in response to environmental change and the availability of new resources. Boomerangs were no longer featured. The early part of the Estuarine Period included naturalistic figures of fish, humans and other subjects. Later decorative and descriptive representations of the X-ray style, for which the region is famous, were developed and became the dominant style of the period. Many of the X-ray style images are of fish (Plates 2.1 & 2.11), although other animals were also
portrayed in this style (Plate 2.7). The X-ray style has persisted right up until the ethnographic present. Clarity of presentation allows many animals to be identified to species level, such as barramundi (*Lates calcarifer*), mullet (*Liza alata*), salmon catfish (*Arius leptaspis*) and saltwater crocodile (*Crocodylus porosus*). The Estuarine Period also included beeswax figures and the mythical figure of Namarrgon, the ‘Lightning Man’, who was portrayed for the first time, reflecting the evolution of the wet season with its accompanying violent electrical storms.

The Estuarine Period was succeeded by the ‘Freshwater Period’, from 1500 years ago. Freshwater faunal and floral species were depicted, such as jabirus (*Ephippiorhynchus asiaticus*), waterlilies (*Nelumbo nucifera*) and magpie geese (*Anseranas semipalmata*). Most of these paintings were in the descriptive and decorative X-ray style. People were portrayed hunting with specialised equipment, such as bundles of short spears mounted in long spearthrowers, or poling rafts to collect waterbird eggs. Hunters were also shown carrying fans made from birds’ wings (Chaloupka 1984, 49; 1985, 277–8; 1993, 185–9).

The style of paintings in the ‘Contact Period’ (from about 300 years ago till the recent past) differed from those in previous periods only in the choice of subject matter. Depictions of items such as guns, ships and introduced animals became common (Plate 2.3). Blue dye obtained from a European laundry whitener, ‘Reckitt’s Blue’, was used in some paintings. Sorcery paintings and decorated hand stencils were also characteristic of this period (ANPWS 1991b, 29; Chaloupka 1985, 278; 1993, 191–215). Most of the rock art from the Contact Period was painted by skilled artists. However unrefined depictions, referred to as ‘rubbish paintings’ by Aboriginal people and ‘casual art’ by Chaloupka, were a brief aberration. They were produced late in this period by people unskilled in the old techniques as a result of having grown up in townships, missions and settlements (Chaloupka 1993, 214–5).

In an alternative analysis of the art, Lewis (1988) expanded Brandl’s (1973) chronology of styles, and then divided this sequence according to changes in the main types of weapons depicted. Thus, he defined a ‘Boomerang Period’ (dominated by the plateau-wide dynamic figures) (Plates 2.5 & 2.9) which he suggested is a minimum of about 9000 years old; a ‘Hooked Stick/Boomerang Period’ (with new weapon types, distinct regional styles of human figures and the appearance of the
plateau-wide yam figures) (Plate 2.6) between about 9000 and 6000 years ago; a 'Broad Spearthrower Period' (figures with short, broad spearthrowers) from about 6000 to between 1000–2000 years ago; and a 'Long Spearthrower Period' (figures with long, narrow spearthrowers, the plateau-wide X-ray art and other recent styles) (Plates 2.7 & 2.11), probably no older than 1000 years. He suggested absolute dates for these periods by relating his analysis of subject matter and distribution patterns to regional archaeological changes in stone artefact technology; environmental evolution of the floodplains; and dates for the presence of animals which are now extinct on the Australian mainland, the Tasmanian devil (Sarcophilus harrisi) (skeletal remains were found in one site which dated to 3100 years ago), and the Tasmanian tiger (Thylacinus cynocephalus) which became extinct about 2000 years ago (Plate 2.8). Lewis considered that some changes in spear technology were directly related to the changes in resource base.

Lewis (1988) saw the plateau-wide distribution of dynamic figures as reflecting either larger group territories or strong inter-group alliances, or both. He suggested that such territorial and social organisation existed in the arid environment which prevailed in Arnhem Land until 9000 to 10 000 years ago. The subsequent change to distinct regional styles he attributed to the breakdown of these social alliances, as a result of population pressures caused by the loss of land as the sea rose after the last glacial maximum. Lewis argued that paintings of the Rainbow Snake which incorporated various animal parts fell within the 'Hooked Stick' period and were a symbol of inter-group unity. The various animal parts represented different 'clan' totemic animals and the paintings represented a ceremony involving different groups, which was developed to counter the tendency towards social breakdown. He saw the re-emergence of a plateau-wide style, generally termed 'X-ray art', as evidence of the return to relative social stability throughout the Arnhem Land plateau.

'Bula' and 'Jawoyn X-ray' styles

The country of the Jawoyn people extends into the southern part of Kakadu National Park. The boundaries between Jawoyn country and Mayali country to the north are blurred, although the two groups share many sites of cultural significance. The art in the southern part of Kakadu is similar to that in the north, but there are some significant
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differences in style. It incorporates features found in both the northern part of the Park and in more arid areas south of Kakadu, as well as exhibiting its own unique traits (ANPWS 1991b, 29).

The bichrome and polychrome paintings of southern Kakadu are dominated by two distinctly different types; the ‘Bula’-type images, named after the predominant association of these images with the Bula tradition (Gunn 1992), and the ‘Jawoyn X-ray’ style (Chaloupka 1981a; 1994, 170). Aborigines believe the Bula paintings are of and by the creation beings themselves; they are said to have ‘put themselves’ on the rock face. The traditional custodians do not wish these images to be publicly viewed, nor photographed or reproduced (ANPWS 1991b, 29; Cooper & Gunn 1987; Gunn 1992).

The ‘Jawoyn X-ray’ style is characterised by polychrome paintings of humans and animals (Plate 2.7). In contrast to the northern part of Kakadu, where fish are the dominant species portrayed in the X-ray style, macropods occur at many of the sites with X-ray paintings in southern Kakadu, reflecting the drier conditions there (Taçon 1993). The human figures are depicted with very fine and distinctive decorative infill (ANPWS 1991b, 29; Chaloupka 1993, 170; Gunn 1992). The older monochrome art styles noted above also occur in southern Kakadu in almost identical form as the north, providing evidence for the wide cultural homogeneity of this earlier period (Lewis 1988).

**Change and continuity**

The diverse range of archaeological sites found throughout Kakadu has provided evidence enabling documentation of early settlement in northern Australia and changes in Aboriginal society over at least 25 000 years and perhaps as long ago as 60 000 years. Archaeological investigation of occupation sites over the past three decades has revealed a hunter-gatherer society adapted to the arid conditions of the late Pleistocene. Subsequent changes in economy, technology and material culture have been correlated with the changing environment and the availability of new resources following the late Pleistocene/early Holocene rise in sea level. Further changes in site use and settlement patterns during the mid to late Holocene period have been interpreted as a result of the establishment of estuarine and later freshwater conditions on the floodplains. Overall the archaeological
PLATE 2.1 Rock art at Ubirr (Jean-Paul Ferrero/AUSCAPE).
PLATE 2.2 Collecting archaeological artefacts at an open site in Kakadu National Park (Ivan Haskovec/ANCA).

PLATE 2.3 Contact period rock art (Ivan Haskovec/ANCA).
PLATE 2.4 Nambulwinjbulwinj (Ivan Haskovec/ANCA).

PLATE 2.5 Dynamic figure, man with dilly bag and two spears (Ivan Haskovec/ANCA).
PLATE 2.6 Yam figures (Ivan Haskovec/ANCA).

PLATE 2.7 X-ray style rock possum (Ivan Haskovec/ANCA).
PLATE 2.8 Example of a naturalistic figure depicting the extinct thylacine (Thylacinus cynocephalus) (Darrell Lewis).

PLATE 2.9 Dynamic figure spearing emu (Darrell Lewis).
PLATE 2.10 Post-dynamic figures (Darrell Lewis).

PLATE 2.11 Example of the X-ray style depicting a barramundi (Lates calcarifer) (Darrell Lewis).
evidence has presented a view of a stable yet dynamic Aboriginal hunter-gatherer culture, well-adapted to local conditions and quick to take advantage of new opportunities as they arose (ANPWS 1991b, 86).

Documentation of the art has enhanced the evidence from the occupation sites by providing details of economic activities, technology and material culture, often missing because of poor organic preservation. It also imparts insights into ideology, religion and other cultural aspects which are not preserved in the material record (Chaloupka 1993, 78). The development and change in rock art styles have reflected an Aboriginal society adapting to environmental change. Early art styles, such as the dynamic figures, are widespread throughout Kakadu and the Arnhem Land plateau, probably reflecting the broader social groupings characteristic of societies in arid areas. As the climate in the Kakadu region became wetter and more productive, and the rising seas pushed coastal groups further inland, the range of art styles became more regionalised and diverse. With the stabilising of sea levels, regional diversity of art styles declined and X-ray art eventually became dominant throughout the Kakadu region and beyond (ANPWS 1991b, 86).

Although diversity and change are characteristic of Kakadu's past, the accent is on continuity. The cultural sites of Kakadu document the continuous development of local hunter-gatherer societies through the late Pleistocene and the Holocene, and the success of their adaptations to a changing environment and new situations. In the occupation sites, new economies and technologies overlie and continue together with the old. Although there are stylistic variations, the rock art reflects the basic cultural unity of Kakadu and the Arnhem Land plateau, and records the history of the region and a religious tradition which links the people with the land over many thousands of years (ANPWS 1991b, 86; Chaloupka 1983, 4–5; 1985, 269; 1993, 87; Jones & Bowler 1980, 15–16).

2.3 Sacred sites

The concept of a 'sacred site' has gained broad recognition in Australian public affairs over the last two decades. The anthropologist Ken Maddock has commented that the 'idea of a sacred site has become part of the furniture of the Australian mind, in spite of disagreement about the meaning of the term and disputation over its application to
particular places’ (Maddock 1988, 305). In law, and often in common usage, the term is used inclusively to refer to any place that is of significance according to Aboriginal tradition. It is worth looking into such a large grab-bag to discern the principles by which significance may be attached to locations in the Kakadu landscape.

As the term itself suggests, ‘sacred site’ is fundamentally a religious notion, and it refers us to Aboriginal cosmology and its doctrines. In this worldview, in the original Creation period, ancestral figures travelled across a featureless landscape. Their movements and actions were of foundational significance for both the physical and social worlds. A path of travel might create a river channel, an object used and left behind might be transformed into a tree or rock formation, and some aspect of the ancestor’s final presence, dormant but still powerful, might be recognised in the shape of a range of hills or the colours of a cliff face.

This capacity for transformation is central to the Aboriginal conception of ancestral figures. Thus, the names of various ‘dreamings’ in Kakadu, such as Lightning, Mosquito, or Freshwater Crocodile, each refer to one manifestation of an ancestor that might also be said to have walked around in human form. Places that take their meaning from the actions of that ancestor are now seen as significant for the reproduction or control of the relevant species or the occurrence of the natural phenomenon, and may themselves be perceived as retaining some essence of, or even to be the final transformation of, the ancestral figure.

The continuing presence of ancestral forms, traces and powers at particular places in Kakadu remains an important consideration in managing the landscape. Though the majority of these djang, or dreaming places, can be safely approached, some are affected by behavioural restrictions, such as the cleaning of fish in certain waterholes, and a small number, where important and powerful Creator beings are resting, are dangerous under any circumstances. The powers immanent there are believed capable of effecting disturbances to the natural order of the world, disturbances which in the most extreme case would be of apocalyptic scale.

This view of a vivified and powerful landscape has been manifested in Aboriginal interpretations of events in Kakadu. An unseasonal rainy period was attributed by one commentator to disturbance caused to a downstream dreaming place by bridge construction for the Kakadu
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Highway, and attributed by another commentator to fishing by a young Aboriginal man in an inappropriate billabong. Accidents befalling visitors to the Park have been seen as an unavoidable concomitant of their intrusion upon places that need to be treated cautiously. In the earlier years of the buffalo shooting industry (see chapter 3), a white shooter contracted leprosy as a result, it is said, of walking into an area of swamp associated with sickness (Keen 1980, 160). Earth tremors felt in the Katherine region in the late 1980s raised fears about activities taking place in the area of an especially dangerous cluster of sites now in the southern section of the Park (see below). In these and other cases, local Aborigines have interpreted irregular occurrences as indicators of improper disturbance in the vicinity of a powerful place.

Two particular Creator figures that were active in the Kakadu region, and which attract much concern of this kind, are the Rainbow Serpent and Bula. The Rainbow Serpent is known to be a powerful and dominating figure across large areas of Aboriginal Australia (Mountford 1978), and sites at which he is said to rest are widespread, including in Kakadu. These are often deep black waterholes, such as escarpment waterfall plunge pools. Bula, by contrast, is a highly localised figure which travelled from the north coast across the Alligator Rivers region to the northern reaches of Jawoyn country. All of the sites associated with him are located in this latter area, now predominantly incorporated within the southernmost sector of the Park.

The relationship between people and sites, and the responsibility of people for sites, is organic because they come from the same ancestral source. That is, ancestral figures not only caused the physical landscape to be shaped in a particular manner, but disposed social groups and their languages across that landscape in a specific pattern. The pioneer ethnographer, Baldwin Spencer, during his research visit to Oenpelli in 1912, recorded from his Gagudju informants the name of the female Creator figure, 'Imberombera', responsible for establishing Aboriginal society in the Kakadu region.

As she travelled along, Imberombera sent out various spirit children to different parts of the country, telling them to speak different languages. She sent them to ten places... Each of these places is regarded as the central camping ground of their respective tribes.
Imberombera is thus supposed to have been the founder of the ten tribes... all of whom, at the present day, inhabit the Cobourg Peninsula and the country east and west of this, for some distance, along the coast line, as well as the inland parts drained by the East, South, and West Alligator Rivers (Spencer 1914, 277–78).

Imberombera (Yimberrumburr, known also as Warramurrungundji) is further said to have sent out the original human procreators of the groups belonging to each country, through whom the spirit-children were born into human form, and to have instituted a system of marriage between these groups (Spencer 1914, 279–89). Much of Spencer’s information relates to groups no longer existing (see chapter 3), and later research has cast doubt on aspects of his account (Keen 1980, 90–95), but the broad cosmological view that it reveals remains relevant, and corresponds with similar stories recorded from people in the Park (Keen 1980, 144, 198–200).

The current Aboriginal owners of Kakadu articulate with particular areas of country primarily through two forms of social organisation, membership of which are ideally determined patrilinearly (by descent through the male line). These are the language group, and a form known as the gunmogurrngurr in the north of the Park and known as mowurrwurr among the Jawoyn in the south (Keen 1980; Merlan 1992). These two forms intersect in an irregular fashion to produce more specific land-holding groups, known to anthropologists as clans, each of which owns an estate: Mirarr Gundjeihmi of the Jabiru–Mudginberri area, Badmardi of the Deaf Adder Gorge area etc. The extent of an estate is a function of the distribution of sites owned and looked after by the clan. These distributions show that clan estates in the northern part of the Park tend to be relatively discrete and bounded, while the mowurrwurr estates in Jawoyn country are overlapping and less easily defined.

This relationship between social groups and sacred sites has been of major political significance in recent times. The passage of the Aboriginal Land Rights (Northern Territory) Act through Federal Parliament in 1976 established a means by which Aborigines have been able to win freehold title to that unalienated Crown land for which they could prove traditional ownership (see chapter 1). Proof of traditional ownership required that they bring themselves within the terms of the definition of ‘traditional Aboriginal owners’ in the Act. The onerous part
of that definition focuses squarely on the relationship between groups and sites. Thus, land claimants have had to show that they are a local descent group, of the kind discussed above, and have common spiritual affiliations to a site on the land, being affiliations that place the group under a primary spiritual responsibility for that site and for the land (Section 3).

Aboriginal claimants for land in Kakadu have had mixed success in satisfying the several aspects of this definition before the Aboriginal Land Commissioner. The first land claim, heard by the Ranger Uranium Environmental Inquiry in 1977, succeeded over almost all of Kakadu Stage One (Fox et al. 1977). The Alligator Rivers Stage Two Land Claim in 1980, over that part of Kakadu most severely affected by historical processes of depopulation and movement (see chapter 3), succeeded only in minor part (Toohey 1981). In 1992 the Northern Land Council mounted a major field effort that allowed strong presentation of the Jawoyn (Gimbat Area) Land Claim over the southern part of Stage Three, featuring documentation of and visits to, sometimes on a restricted basis, some of the most impressive art sites and powerful sacred sites associated with the Creator figure Bula. The Commissioner's report on this claim is pending at the time of writing. A further claim has been lodged, but not yet proceeded with, over the former Goodparla Station which now comprises the south-western sector of the Park.

Practical custodianship of sites is a function in the first instance of birth into the local descent group that has primary responsibility, and then of seniority within that clan and of knowledge of the places and their meanings. Where knowledge within the primary land-owning clan is poor, by reason of the age or life histories of the surviving members, then more knowledgeable people from other clans may assist in discharging custodial obligations towards those sites. The evidentiary burden of proving a land claim falls disproportionately on these individual traditional owners.

The legislative changes of the 1970s also gave recognition to site custodians within the process of approving development projects. Legislation complementary to the Land Rights Act established an Aboriginal Areas Protection Authority (formerly Aboriginal Sacred Sites Protection Authority) charged with documenting and registering sites in
the Northern Territory and liaising with custodians regarding their protection. A number of sites have been registered in the Kadadu area, in most cases before they were protected by Park declaration.

Responsibility for sites has continuing significance with respect to development proposals inside the Park. The Australian Nature Conservation Agency maintains its own site register, and its consultation program takes account of Aboriginal site sensitivities in planning Park land use and facilities (ANPWS 1991a). Particularly in recent years in the southern sector of the Park, this has demanded an extended period of discussion with Jawoyn custodians concerning visitor access to bushwalking tracks, camping grounds and art sites, in an area containing a cluster of sensitive and dangerous places. Other organisations operating in Kakadu have had to accommodate the same concerns. Field research on the Magela flood plain by the Office of the Supervising Scientist, for example, had to be pursued in a manner acceptable to custodians of a dangerous site in that area.

Most prominent, however, have been issues arising from mining proposals. Two in particular have raised sacred site issues to the level of national concern, prior to Park declaration over the respective areas. During the Ranger Uranium Inquiry, one of the major Aboriginal objections to the proposed development was its proximity to two sensitive and dangerous sites around Mt Brockman. The Inquiry recommended that the southern boundary of the mining lease should be placed at a point of compromise between those requested by the mining company and the Northern Land Council, such that No 1 ore body could be mined, but further investigation of the No 2 radiometric anomaly, located within a few hundred metres of Mt Brockman, was prevented (Fox et al. 1977, 283–84). The other issue arose over Coronation Hill in the south of the Park, following its registration as a sacred site by the relevant Northern Territory Authority in 1985. This long and complex dispute was resolved ultimately by Federal Cabinet in 1991, which precluded development of a proposed mine and allowed incorporation of the area into Kakadu.

A notable feature of the Coronation Hill issue was the importance placed by Aboriginal custodians on rock art, and especially on certain motifs representing the Creator figures and said to have been placed on the rock by those figures (Gunn 1992). The prominence given to this
manifestation of sacredness was a salient reminder that signs of the activities of Creator beings may be apparent in many forms to the Aboriginal gaze. Moreover, ceremonial sites, that is places created by human action, such as the formation of stone arrangements or the gathering of painted bones, and dedicated to the purpose of human dealings with sacred symbols and entities, may also be considered significant, even after the ritual practices have been abandoned.

The concluding passage that follows comes from the work of the anthropologist Peter Sutton on Aboriginal art in Australia. It serves both to summarise the main theme of this section, and to suggest its implications for understanding the original human view of the Park:

The Ancestral Beings, or Dreamings, who carved forms out of the formless world and molded the shapes of the creeks and desert sandhills and rainforests also brought human sociality and culture. Thus, there is no geography without meaning or without history... The land is already a narrative – an artifact of intellect – before people represent it. There is no wilderness (Sutton 1988, 19).

2.4 The seasonal cycle

The great variety and number of sites reviewed so far in this section – deposited sequences, open sites, art and sacred sites – testify not only to the richness of the Aboriginal heritage in the Kakadu landscape, but are also a material manifestation of Aboriginal life patterns in this environment. Current Aboriginal testimony and practice complement this material legacy to reveal much of the Aboriginal ecology of Kakadu.

Aborigines in Kakadu perceive the annual cycle to be divided into six named seasons (Figure 2.1). The progress of these is marked not by fixed dates, but by observed and regular changes of weather, and of plant and animal life. (The names that follow are in the Gundjeihmi (Mayali) language.) Thus, the heavy rain season of Gudjewg is followed by Bang-Gerreng, when strong south-easterlies flatten the tall brown spear grass. The beginning of the dry weather, Yegge, leads into the first firing of grasses. Larger areas are cleared by fire through the cold-weather time of Wurrgeng. The weather warms in the late dry of Gurrung, until the humidity rises and electrical storms build in Gunumeleng, as winds again come from the north-west and the first scattered monsoon rains fall (ANPWS 1980).
Figure 2.1 Seasonal calendar for the Kakadu region in Gumbeyhni (Mayali) language.
With this seasonal cycle and the oscillation of wet and dry, groundwaters expand and contract, and a succession of food sources come into season. Different plant and animal resources are best harvested at particular times, when they have reached maturity or are in localised abundance. This pattern of availability had major implications for traditional Aboriginal articulation with the physical environment, and continues today to determine usage of the bush. This, then, is a further dimension of the relationship between Aborigines and country.

The previous section focussed on religious meanings in the landscape, and discussed the centrality of those meanings for the organisation of land-owning groups and for the distribution of custodial responsibilities. The localised and specific character of ownership and responsibility contrasts with more expansive and opportunistic practices in the exploitation of material resources. Research in many areas of Aboriginal Australia has shown that the estates of individual land-owning groups were typically neither large nor diverse enough to satisfy all the material requirements of group members. They therefore hunted and foraged not only over their own estates, but also over the estates of other groups (Hiatt 1962; Stanner 1965). Usage of these other estates was generally arranged through relationships established by intermarriage, kinship and ceremonial co-operation, and, in western Arnhem Land, through a relationship known as ‘company’ that could manifest itself in a pattern of close exchange and sharing between contiguous clans. By such means, the Aboriginal population could gain access to the full range of resources available in a region, subject to their observation of the appropriate social protocols.

In a region such as Kakadu, in which marked seasonal changes combine with equally dramatic differences in topographical zones from coastal estuaries, fresh water swamps, lowland woodlands, to the sandstone Arnhem Land plateau, resource availability is highly uneven over both space and time. Evidence from many sources – archaeological, archaeobotanical, ethnographic, historical – combines to reveal a human ecology of the Kakadu area organised around strategic movements between zones of habitation and exploitation over the course of the year.

Most notable of these was the mid-to-late dry season concentration on the downstream wetlands, where, in addition to edible plants, many kinds of fauna clustered on shrinking bodies of water. The extensive,
open scatters of artefacts around these swamps (see this chapter) are a legacy of large-scale Aboriginal harvesting of these food sources (Brockwell 1989). Waterfowl were a bountiful attraction for Aboriginal hunters during this period, and their mode of procuring them was a dramatic application of local exploitive technology. Tom Cole, who shot buffalo in the Kakadu area in the 1930s, wrote of his first encounter with this technique on the wetlands of the South Alligator River:

Geese were there in millions, landing, taking off and just paddling around sticking their heads into the water. The din of their squawking was almost deafening. The most interesting feature was the goose-killing that was going on: I’d never seen anything like it in my life.

The entire lagoon was ringed by huge paperbark trees that were very tall, probably more than a hundred feet in height. To my amazement, standing up in the topmost branches and swaying crazily, were three naked Aborigines, their feet planted on two or three cross-sticks stuck in forks of the branches. Because of the foliage I couldn’t see very clearly but as the birds skimmed the treetops the trio let fly with short sticks. They were so close to their targets they didn’t have to be exceptional marksmen, but they certainly had to be outstanding acrobats (Cole 1988, 257–8).

With the approach of the wet season, bands of people began dispersing across the Kakadu landscape. Some remained on the lowlands, even in the immediate vicinity of expanding water bodies. Others moved to a sequence of shelters located in sandstone outliers, escarpment valleys and areas of the Arnhem Land plateau. It is probable that this pattern of dispersal roughly reflected a broad cultural division that transcended the more localised land-owning groups. The Aboriginal cultural geography of the region features a distinction between the ‘top side’, ‘stone country’ or ‘freshwater’ groups of the escarpment and plateau, and the ‘bottom end’, ‘swamp country’ or ‘Alligator’ groups of the wetlands and floodplains. This ecological division is complemented by differences in language and ceremonial repertoire (Keen 1980, 88–89).

This pattern of extensive and diverse articulation with Park environments is well illustrated by an account of the annual movements of a local band provided, prior to his death in 1987, by a senior and prominent member of Badmardi clan of Deaf Adder Gorge (Chaloupka 1981b). The travels of this group ranged from Oenpelli in the north to the upper Katherine River in the south, and included visits to the
wetlands to harvest, as well as those foods mentioned above, goose eggs available in the late wet season. This range of movement not only allowed access to the varied resources of the country, but also afforded opportunities to renew social contacts and ceremonial relations with members of other language groups whose territories they passed over, and whose own routes of travel they intersected. An important theme illustrated by Chaloupka's account of the Badmardi year is that traditional Aboriginal ecology is never solely a strategy of resource exploitation. Rather, practical utility is one value that is met within a pattern of life that renews and reproduces relations with country, with dreamings, and with other people.

2.5 Traditional resources: bush tucker

In the preceding section we have introduced concepts concerning traditional patterns of movement over the regional landscape with respect to both the seasonal availability of resources, and social and religious obligations. In this section we consider specifically the availability of traditional resources, particularly foods or 'bush tucker', in more detail. The brief account given below is by no means exhaustive, however, and focuses on resources traditionally utilised by Gundjejhmi, or Mayali, people living in the central Kakadu region. Maritime resources utilised by people living in coastal areas of the Park are not discussed here given that little documented information is currently available; however, an excellent reference to the traditional resources of coastal habitats is available for the Blyth River area of north-central Arnhem Land (Meehan 1982).

Aboriginal people living in the central Kakadu region continue to hold detailed knowledge of the usages, availability, and ecology, of some hundreds of plant and animal species. A listing of plants utilised traditionally by Gundjejhmi people other than for foods is given in Table 2.1. Although this list is doubtless incomplete, it does provide a good indication of the range of plant usage in the traditional regional material culture. Of particular note is the evident detailed knowledge of the usage of plants as fish poisons or ichthyocides, and the extensive use of fibres for the making of fishing nets and traps. Such observations highlight the obvious significance of fishing in the traditional economy.
Table 2.1 Traditional usages of plants by Gundjeihmi people, other than for foods, in the central Kakadu region (after Lucas & Russell-Smith 1993)

| Culinary herbs | Acacia gonocarpa, Comesperma aphyllum, Corynothera lateriflora, Ectrosia leporina, Gardenia fucata, Melaleuca argentea, Melaleuca cajuputi, Melaleuca viridiflora |
| Beverages | Cymbopogon procerus, Livistona humilis, Livistona inermis, Pandanus spiralis |
| Sweet snacks | Eucalyptus miniata, Grevillea pteridifolia, Heteropogon triticeus, Melaleuca viridiflora |
| Medicines | Key: (1) Pain relief, (2) antiseptic treatment of wounds, (3) colds etc, (4) eye medicines, (5) diarrhoea, (6) bandage |
| | Acacia difficilis (1), Allosyncarpia ternata (2), Amyema spp. (2), Asteromyrtus symphyocarpa (3), Buchanania obovata (1), Cymbopogon procerus (3), Decaisinina spp. (2), Dioscorea bulbifera (2), Erythrophleum chlorostachys (1), Exocarpus latifolius (2), Flagellaria indica (2.4), Grewia retusifolia (2), Jacksonia dilatata (4), Morinda citrifolia (3), Opilia amentacea (4), Pandanus spiralis (1), Pityrodia sp. (2), Protasparagus racemosus (2), Senna lepochtala (2), Tacca leontopetaloides (5), Tinospora smilacina (1, 2), Tridax microstachya (1,3), Urticaria aurea (6), Xanthostemon psidioideae (3) |
| Mosquito repellants | Callitris intratropic, Croton arnhemian, Exocarpos latifolius, Ficus leucotricha, Triodia microstachya (resinous-leaved form) |
| Fish poisons | aniki, Acacia auriciliformis, Acacia dimidiata, Acacia holosericea, Acacia oncinocarpa, Barringtonia acutangulum, Cajanus spp., Cassia spp., Crotalaria crassipes, Denharnia obscura, Distichostemon hispidulum, Eucalyptus clavigera (gum), Eucalyptus polycarpa (gum), Grevia vernicosa, Pimelea sp., Planchnia careya (gum), Polycarpae longiflora, Senna spp., Strychnos luoida, Tephrosia spp. |
| ‘Tobacco’ | Eucalyptus clavigera (ash mixed with tobacco), Pterocaulon spachelatum, Striga curviflora |
| Wooden implements: spears, spear throwers, digging sticks | Acacia aulacocarpa (2), Acacia auriciliformis (2), Acacia conspersa, Acacia holosericea (1), Acacia latecens (2), Acacia latifolia (2), Acacia mimula (2), Acacia sericata (2), Asteromyrtus magnifica (2), Asteromyrtus symphyocarpa (2), Atalaya vanifolia (2), Bambusa arnhemica (1), Callitris intratropic (2), Calophyllum sil (2), Calyx spp. (2), Choriceras bicornis (3), Croton bymesii (3), Diospyros calycanthus (3), Doliachodine filiformis (2), Drypetes lasiogyna (2), Dysoxylum acutangulum (2), Erythrina vespertilio (3), Erythrophleum chlorostachys (2), Eucalyptus polycarpa (2), Gyrrocarpos americanus (1), Hakea arboreascens (2), Hibiscus anhemiasis (1), Hibiscus tilicaceus (1), Lithsea glutinosa (3), Lophopetalum arnhemicus (3), Maranthes corymbosa (3), Miliaea spp. (3), Myristica inspida (2), Persoonia taldac (3), Phragmites karka (1), Planchonella spp. (3), Polyalthia spp. (3), Regelia puncea (2), Stenocarpos spp. (2), Templetonia hookerii (2), Terminalia grandiflora (3), Terminalia pterocarya (3), Verticordia spp. (2), Wrightia spp. (3), Xanthostemon psidioideae (2) |
| Strong binding adhesives for implements | Acacia difficilis (gum), Callitris intratropic (gum), Erythrophleum chlorostachys (gum) |
| Sandpaper | Ficus opposita, Ficus scobina |
**Table 2.1 (continued)**

<table>
<thead>
<tr>
<th>Category</th>
<th>Plants/Seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Firesticks</strong></td>
<td>*Brachychiton diversifolius, Clerodendrum floribundum, Cochlospermum fraseri,</td>
</tr>
<tr>
<td></td>
<td>Croton amnhecus, Dolichandrone filiforme, Ficus opposita, Ficus scobina,</td>
</tr>
<tr>
<td></td>
<td>Flagellaria indica, Grewia sp., Hibbertia spp., Hibiscus spp., Keradrenia sp.,</td>
</tr>
<tr>
<td></td>
<td>Premna acuminata, Wrightia saligna</td>
</tr>
<tr>
<td><strong>Pipes</strong></td>
<td><em>Clerodendrum floribundum, Mackinlaya macrossiadi, Persicaria spp.</em></td>
</tr>
<tr>
<td><strong>Didjeridoos</strong></td>
<td><em>Eucalyptus spp., Terminalia pterocarya</em></td>
</tr>
<tr>
<td><strong>Water craft</strong></td>
<td><em>Dug-out canoes: Alstonia actinophylla, Bombax ceiba, Brachychiton diversifolius, Canarium australium, Ganophyllum falcatum, Maranthes corymbosa, Nauclea orientalis</em></td>
</tr>
<tr>
<td></td>
<td>*Other: Bambusa arnhemica (raft, poles), Eucalyptus tetrodonta (bark canoe),</td>
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<tr>
<td></td>
<td>Melaleuca spp. (bark canoe)*</td>
</tr>
<tr>
<td><strong>House-sheeting</strong></td>
<td><em>Eucalyptus tetrodonta, Melaleuca spp.</em></td>
</tr>
<tr>
<td><strong>Fibres</strong></td>
<td><em>Acacia difficlis (1), Acacia latifolia (1), Brachychiton diversifolius (1),</em></td>
</tr>
<tr>
<td></td>
<td><em>Brachychiton megaphyllus (1), Clerodendrum floribundum (1), Cyperus decompositus (2), Cyperus javanicus (2), Cyperus laxus (2), Ficus virens (1), Flagellaria indica (1), Grewia sp. (1), Hibiscus arnhemensis (1), Hibiscus tiliaeus (1), Malaisia scandens (1), Melochia corchorifolia (1), Pandanus aquaticus (1,2), Pandanus spiralis (2), Planchnia careya (1), Sterculia quadrifida (1), Trionia spp. (2)</em></td>
</tr>
<tr>
<td><strong>Dyes</strong></td>
<td><em>Antidesma ghaesembilla (purple), Cyperus scariosus (red, black), Eucalyptus clavigera (with Pogolobus, red), Haemodorum spp. (red), Litsea glutinosa (black), Livistona humilis (pink, black), Livistona inermis (pink, black), Morinda citrifolia (yellow), Nymphaea macroserperma (purple), Nymphaea pubescens (blue), Pogonolobus reticulatus (yellow, black, and with Eucalyptus clavigera red)</em></td>
</tr>
<tr>
<td><strong>Soaps</strong></td>
<td><em>Acacia auriculiformis, Acacia difficlis, Acacia holosericea</em></td>
</tr>
<tr>
<td><strong>Cooking implements</strong></td>
<td><em>Alphitonia excelsa (2), Ampelocissus acetosa (2), Carpentaria acuminata (1),</em></td>
</tr>
<tr>
<td></td>
<td><em>Ganophyllum ramsayi (1), Melaleuca spp. (1,2)</em></td>
</tr>
<tr>
<td>**Ornamentation/</td>
<td><em>Abrus precatorius (3), Alstonia actinophylla (1), Brachychiton diversifolius (4),</em></td>
</tr>
<tr>
<td>painting**</td>
<td><em>Cymbidium canaliculatum (5), Dendrobium affine (5), Eucalyptus tetrodonta (6),</em></td>
</tr>
<tr>
<td></td>
<td><em>Flagellaria indica (2), Gymnanthera nitida (1), Hoya australis (1), Ichnocrampus frutescens (1), Leptocarpus spathaceus (2), Pandanus aquaticus (4), Tylophora benthamii (1)</em></td>
</tr>
</tbody>
</table>

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PLATE 2.12. Waterlilies provide an abundant source of food, with roots, stems, and fruits all being eaten. Here, Minnie Gapindi is gathering one of the three main edible waterlily species occurring on the floodplains of Kakadu, mardjarkarlang (Nymphaea macrosperma) (Diane Lucas).
While many species are, and probably were, utilised only occasionally (eg most waterbirds), or eaten more in the manner of snack foods (eg many fruits), the major regional staples comprised some 12 species of plants and 19 animal species (Table 2.2).

Yams (tubers) are most commonly eaten of the staple plant species, typically after light roasting. One staple yam species, *angindjek* (*Dioscorea bulbifera*), requires considerable preparation involving slicing, thorough washing and overnight leaching before cooking. The highly nutritious seed heads of the three water lilies (*Nymphaea* spp.), *andem,*
PLATE 2.14 The fruits of mardjarkarlang can be eaten raw, lightly cooked or, as shown here, prepared by being ground up and formed into small cakes before cooking (Diane Lucas).

PLATE 2.15 In the wet season the large yams (tubers) of gaamaing (Amorphophallus paoniiifolius) provided an important traditional staple. Here Minnie Gapindi is uncovering gaamaing after cooking in a traditional ground oven (Diane Lucas).
PLATE 2.16 Floodplains provide a major source of animal foods. Here Minnie Gapindi is smoking out a large bolorgoh (water python – Lialis fuscus) (Diane Lucas).

PLATE 2.17 Guluban (flying-foxes – Pteropus spp.) are a favourite food of Aboriginal people. Here guluban are being cooked in a traditional ground oven (Diane Lucas).
yalgey and mardjarkarlang, which were also major staple foods, were probably even more important to the traditional economy than yams (Plate 2.12). These seed heads can be eaten raw or, as was done in the past, ground up and formed into small cakes (Plates 2.13 & 2.14). Whereas cycads (Cycas spp.) provide a major staple food in eastern Arnhem Land and, at least in the past, in other parts of Australia also, they were apparently little utilised in the Kakadu region, despite their occurrence there in a few localised populations.

Of the animal species that provided the mainstay of the protein diet, it is probable that fish and reptiles were the most common dinner items over the yearly cycle. In Table 2.2 we have listed four large fish species as staples (annakawarri – salmon catfish; dunbukman – black bream; namanggorl – barramundi; guloibirr – saratoga), but it is clear that a range of fish provided a ready and plentiful resource. For example, many Aboriginal people today go fishing for bourd (spangled grunter – Leiopotherapon unicolor), typically a small fish which may be readily caught on a hook; in the past, such fish were easily caught in small waterholes as they dried out either using scoop nets (eg see McCarthy & McArthur 1960) or fish poisons. Though more seasonal in availability, a variety of reptiles were also staple items, including at least three large monitors (a type of lizard), two snakes (Plate 2.16), three freshwater turtles and the eggs of both crocodile species occurring in the region. Although some birds and mammals are highly prized prey (eg alwandjuk – emu; benuk – plains bustard; gohwarrang – echidna; barrk – male black wallaroo), only banarru (maggie goose), gornobolo (agile wallaby), and the two flying-foxes, nagaiyalak (little red flying-fox) and nanggumor (black flying-fox) (Plate 2.17), are sufficiently common to be considered as staple, if seasonal, dietary items. It stands to reason that Aboriginal people were, and continue to be, very familiar with the ecology of all these species.

Turning now to the availability of these staple food resources through the seasonal cycle and the significance of different habitats to the traditional economy, it is evident that for the greater part of the year, riverine communities, and floodplains in particular, were by far the most productive habitats (Figure 2.2). These data thus serve to reinforce the substantial evidence available from archaeological, ethnographic, and historical records discussed previously in this chapter, concerning
the singular importance of floodplains, especially in the latter part of the dry season. Conversely, the data presented in Figure 2.2 illustrate that other habitats, but particularly communities of the sandstone escarpment and plateau, are relatively impoverished with respect to food resources. Such patterns of resource availability have clear implications for our understanding of the organisation of traditional Aboriginal society in the region.

During *Gudjewg*, however, at the height of the wet season when much of the country is in flood, upland habitats, and especially small jungle patches, assume greater importance. Paradoxically, this is a time of year which older Aboriginal people recall as a time of potential hardship,
Table 2.2 Availability of staple foods throughout the year, by habitat, for country utilised by Gundjeyhmi people in the central Kakadu region (after Lucas & Russell-Smith 1993)

Notes: + = food eaten, ++ = important food, +++ = staple food
1 Habitat: F = floodplain; JL = lowland jungle; JS = sandstone jungle; R = riverine; S = sandstone; W = woodland and open forest
2 Seasons: abbreviated names given in full in Figure 2.1

<table>
<thead>
<tr>
<th>Species</th>
<th>Part Eaten</th>
<th>Habitat</th>
<th>Season</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PLANTS</strong></td>
<td></td>
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<tr>
<td>Amorphophalus paeoniifolius (gaamaing)</td>
<td>yam</td>
<td>JL</td>
<td>+++</td>
</tr>
<tr>
<td>(cheeky yam)</td>
<td></td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>Aponogeton elongatus (angodjbang)</td>
<td>yam</td>
<td>R</td>
<td>+++</td>
</tr>
<tr>
<td>Dioscorea bulbifera (angindjek) (round yam)</td>
<td>yam</td>
<td>JL,JS</td>
<td>+++</td>
</tr>
<tr>
<td>Dioscorea transversa (garrbada) (long yam)</td>
<td>yam</td>
<td>JL,JS</td>
<td>+++</td>
</tr>
<tr>
<td>Eleocharis dulcis (anguilaidj) (water chestnut)</td>
<td>yam</td>
<td>F</td>
<td>+++</td>
</tr>
<tr>
<td>Eleocharis sp. (galaarmun) (water chestnut)</td>
<td>yam</td>
<td>F</td>
<td>+++</td>
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<tr>
<td>Ipomoea sp. (anburrey)</td>
<td>yam</td>
<td>S</td>
<td>++</td>
</tr>
<tr>
<td>Nelumbo nucifera (wurramaning) (lotus lily)</td>
<td>yam</td>
<td>F</td>
<td>+++</td>
</tr>
<tr>
<td>Nymphaea macroasperma (mardjarkalang) (water lily)</td>
<td>fruit</td>
<td>F</td>
<td>+++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>+++</td>
</tr>
<tr>
<td>Nymphaea pubescens (yalgey) (water lily)</td>
<td>fruit</td>
<td>F</td>
<td>+++</td>
</tr>
<tr>
<td>Nymphaea violacea (andem) (water lily)</td>
<td>fruit</td>
<td>F</td>
<td>+++</td>
</tr>
<tr>
<td>Triglochin procerum (anbule)</td>
<td>yam</td>
<td>R,F</td>
<td>+++</td>
</tr>
</tbody>
</table>

**ANIMALS**

| Molluscs                                      |            |         |        |
| Velesunio angasi (gurruk) (mussel)            | flesh      | F,R     | +++    |
| Fish                                          |            |         |        |
| Arius leptaspis (anmakawarri) (salmon catfish) | flesh | F | +++    |

**Seasons:**
- Gudj: Good
- Bang: Bad
- Yege: Yeget
- Wurr: Wurr
- Gurr: Gurr
- Gunu: Gunu
<table>
<thead>
<tr>
<th></th>
<th>Diet</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
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<tr>
<td><em>Hephaestus fuliginosus</em> (dunbukmang) (black bream)</td>
<td>flesh</td>
<td>R</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td><em>Lates calcarifer</em> (namanggorr) (barramundi)</td>
<td>flesh</td>
<td>F,R</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td><em>Scleropages jardini</em> (guloibirr) (saratoga)</td>
<td>flesh</td>
<td>F,R</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
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<tr>
<td><strong>Crocodiles</strong></td>
<td></td>
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<tr>
<td><em>Crocodylus porosus</em> (ginga) (salt-water crocodile)</td>
<td>eggs</td>
<td>F,R</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
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<td>++</td>
</tr>
<tr>
<td><em>Crocodylus johnstoni</em> (gumugen) (fresh-water crocodile)</td>
<td>eggs</td>
<td>R</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
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</tr>
<tr>
<td><strong>Lizards</strong></td>
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<td><em>Varanus gouldii</em> (galawan) (Gould's goanna)</td>
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<td><em>Varanus indicus</em> (birrning) (mangrove monitor)</td>
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<td><em>Varanus panoptes</em> (djanai/dalag) (sand monitor)</td>
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<td><em>Acrochordus arafurae</em> (nauwandak) (Arafuran file-snake)</td>
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<td><em>Lialis fuscus</em> (bolorgoh) (water python)</td>
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<td><em>Carettochelys insculpta</em> (warradjang) (pig-nosed turtle)</td>
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<td><em>Chelodina rugosa</em> (burringandji) (long-necked turtle)</td>
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<td><em>Elseya dentata</em> (ngardehwoh) (snapping turtle)</td>
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<td><em>Anseranas semipalmata</em> (bamarru) (magpie goose)</td>
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<td><em>Macropus agilis</em> (gornobolo) (agile wallaby)</td>
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<td><em>Pteropus alecto</em> (nanggumor) (black flying-fox)</td>
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<td><em>Pteropus scapulatus</em> (nagaiyalak) (little red flying-fox)</td>
<td>flesh</td>
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when food resources were often in short supply. Thus, most floodplain yams are unavailable at this time, and the water lilies are not fruiting. In the lowland jungles, however, the abundant yams gaamaing (Amorphophallus paeoniifolius) (Plate 2.15) and garrbada (Dioscorea transversa) are often locally available. With the end of the wet season, in Bang-Gerreng, the time of plenty returns; for example, a wide variety of yam species are available for collection in the open forests and woodlands, and ready access to the floodplains is again possible. Traditionally, important ceremonies were held at this time to mark and celebrate the renewal of the seasonal cycle.

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3
Social history since colonisation

Robert Levitus

3.1 Exploration

Although there remains doubt about which seafaring power was the first to sight or land on the north coast of Australia (Powell 1982, 21–28), the first sustained contact that Aborigines of the Alligator Rivers region had with non-Aboriginal people was with Macassans from Sulawesi and other parts of the Indonesian archipelago. Probably from the last quarter of the seventeenth century (Macknight 1976, 93–97), they visited the north coast of Arnhem Land every wet season until restrictions imposed by the South Australian government brought their operations to an end in the season of 1906–1907.

The Macassans were interested primarily in harvesting trepang, but also collected turtleshell, pearls and pearlshell, and some timber and buffalo horn, all for shipment to Asian markets. Macknight calculates an annual visitation for most of the nineteenth century of at least one thousand men concentrated on the coastline from Cobourg Peninsula in the west to the Pellew Group in the east, working both from their praus and canoes in the bays and at processing sites on the beaches (1976, 29, 36, 43–45).
Dutch maritime explorers are known to have sailed the north coast. Among them, Tasman mapped the eastern opening of Van Diemen Gulf in 1644 (Major 1859, xcvi). The first British navigator to enter the Gulf was Phillip Parker King, who in 1818 named the three Alligator Rivers and entered the two largest of them before sailing to Timor (Figure 3.1). The British subsequently established military outposts at Raffles Bay (1827–29) and Port Essington (1838–49) on Cobourg Peninsula: Alligator Rivers people are known to have visited at least the latter of these places. The next major maritime exploration in the region, that of HMS Beagle in 1839, again entered Van Diemen Gulf but did not touch upon any part of the coast or rivers of Kakadu (Stokes 1846).

In 1845 Ludwig Leichhardt carried out the first European land traverse of the Kakadu region, on his route from Moreton Bay to Port Essington. He travelled down Jim Jim Creek from the escarpment, then down the South Alligator River before crossing to the East Alligator and proceeding north. John McDouall Stuart’s fifth attempt to cross the continent from Adelaide was successful in 1862, when he reached the north coast at Chambers Bay, just to the west of Kakadu (Stuart 1865, 406–11). During the final stage of his journey to the coast, and again when retracing his steps south, he kept to the eastern side of the Mary River along its entire length, thereby travelling just inside the present south-western boundary of the Park (Figure 3.1, Plates 3.1 & 3.2).

The pace of incursion then accelerated. Partly on the basis of Stuart’s report, South Australia successfully argued its case for control of the Northern Territory, and attempted first colonisation at Escape Cliffs, near the mouth of the Adelaide River, from 1864 to 1867. Of the expeditions that set out from there, the most notable was that of McKinlay in 1866. Having been forced to abandon his original plans, he struggled through country soaked with wet season rains as far as the East Alligator. South Australia succeeded in its second attempt at colonisation in 1869 at Port Darwin. From then on, a succession of exploratory and surveying expeditions were sent towards the Alligator Rivers region to assess its productive resources.

The various expeditions mentioned here had divergent experiences in their contacts with local Aboriginal peoples. Moments of genuine first contact were usually accompanied by expressions of fear or violence.
FIGURE 3.1 Approximate routes of major explorers who entered the Kakadu area. Map compiled by R Levitus. King, Leichhardt and Stuart plotted from their journal descriptions. McKinlay plotted by Lloyd Browne from field research.
PLATE 3.1 'Victoria Square, Port Essington' – from Leichhardt’s journal (1847); Leichhardt arrived here at the end of his journey in December 1845 (Libraries Board of South Australia).

PLATE 3.2 'Table Land and Valley of the Adelaide' – from Stuart’s journal (1865); Stuart was about to descend onto the headwaters of the Mary River which he believed to be the Adelaide, on July 10, 1862 (Libraries Board of South Australia).
Robert Levitus

Many people probably observed the explorers from cover. Notably, Stuart saw not a single Aborigine. Leichhardt, in contrast, encountered large, confident and friendly groups on the South Alligator wetlands. These were people who had had contact with the British at Port Essington, and welcomed Leichhardt’s party (Leichhardt 1847, 502–3). On November 26th 1845, for example, he recorded the return to camp of one of his party,

accompanied by a whole tribe of natives. They were armed with small goose spears, and with flat wommalas; but, although they were extremely noisy, they did not shew the slightest hostile intention. One of them had a shawl and neckerchief of English manufacture: and another carried an iron tomahawk, which he said he got from north-west by north. They knew Pichenelumbo (Van Diemen’s Gulf), and pointed to the north-west by north, when we asked for it. I made them various presents: and they gave us some of their ornaments and bunches of goose feathers in return, but shewed the greatest reluctance in parting with their throwing sticks (wommalas.) They were inclined to theft, and I had to mount Brown on horseback to keep them out of our camp (Leichhardt 1847, 492).

3.2 Non-Aboriginal economic activity

Non-Aboriginal economic activity in the Alligator Rivers region remained small scale and diverse for most of its history. For most of that time the area was a Northern Territory backwater, and contributed little to even such limited development as its South Australian and then Commonwealth custodians were able to engender in the Territory as a whole.

During the period of South Australian control of the Northern Territory from 1863 to 1910, official attempts to attract large amounts of permanent, productive capital were repeatedly frustrated, with large investments being lost in cattle stations, mines and agricultural projects. Unlike other Australian colonies, the Territory’s mining booms of the 1870s and 1890s did not bring a permanent jump in population, or the development of service industries and prosperous towns (Kennett 1962, 151–60). Similarly, visions of areas of closer settlement based on small-scale agriculture were destroyed by floods, cyclones, vermin, rodents and other difficulties, while the Darwin–Gulf of Carpentaria district, after optimistic beginnings, was found to be the poorest of the major
pastoral regions in the Northern Territory (Duncan 1967, 24–25). Ultimately the Territory economy rested on pastoralism in other areas: Victoria River Downs, the Barkly Tablelands and Alice Springs district.

This had significant implications for the region between the north-south railway line and Oenpelli. In the absence of a central enterprise or industry to which labour gravitated and around which a constellation of service facilities could develop, economic activity was carried on largely by individuals with little or no initial capital. They took advantage of whatever income-producing opportunities presented themselves from time to time: shooting buffalo for hides or meat, shooting brumbies for hair, prospecting or digging for alluvial minerals, poisoning dingoes for bounty payments, timber-getting, gardening, mustering cattle and shooting crocodiles for skins.

These people, who would have been marginal to economic life in other areas, were in the Alligator Rivers region principal economic actors for much of the time, and the activities they pursued amounted to what might aptly be labelled a 'fossicking economy' (Levitus 1982, 8). This fragmented and shifting scene offered many opportunities for the participation of Aborigines.

The buffalo industry

This industry exploited the large herds of feral buffalo that had grown from animals released from the early settlements on Cobourg Peninsula and at Escape Cliffs, and which had spread across the lowland floodplains and swamps. After one abortive attempt to produce buffalo hides for an Australian market on Cobourg Peninsula in 1876, buffalo shooters began penetrating the areas east of Darwin in the 1880s, aiming to supply an export market through Darwin agents.

EO Robinson is credited with beginning this industry on the Adelaide River (Hill 1951, 371), and was followed by other shooters, operating mostly singly or in pairs, and shooting on foot. Paddy Cahill, the best known of that first generation, introduced the method of shooting from horseback. It is clear that the industry was a major employer of Aborigines in the region from these early years, as evidenced by complaints from Darwin residents about the difficulty of finding domestic help during the shooting season (NT Times 1 Jan 1901).
Buffalo were shot principally for their hides and horns from the 1880s until the mid-1950s. During that period there were fluctuations in the industry: prices collapsed in the early 1920s due to the post-war recession in Europe, salt and ammunition were rationed during World War Two, and markets were finally lost in the 1950s due to poor processing of hides, the emergence of synthetic substitutes, and disruption caused by the 1956 Suez Crisis. Apart from these crises, the fortunes of the industry were also affected by the numbers of buffalo. By the turn of the century, for example, the buffalo on the east side of the East Alligator River had been almost entirely shot out (NT Times 9 Dec 1898).

Buffalo shooting was carried out in the dry season, roughly between May and October. In the wet season the ground became too muddy to pursue the buffalo and hides taken would rot. Shooting was concentrated around the lower reaches of the major rivers, where seasonal flooding left broad open plains bordered by billabongs and swampy depressions. Even after the introduction of horses, footshooters were still necessary for stalking individual animals. Men moved carefully through dense paperbark stands or crawled through thick vegetation, perhaps shooting one buffalo and frightening others out onto the open plain. There, horseback shooters ran with the herds, moving up closely on each buffalo in sequence, bringing down a string of animals in one run.

The buffalo were shot in the spine at the rump and left paralysed until the run was finished and workers followed to kill and skin each beast. Hides were transported back to camp on horseback, and in later years by motor vehicle where the ground was dry and firm. All work up to the delivery of hides to the camp was done by men.

Buffalo camps were established next to bodies of water – billabongs, swamps or springs – in order that the hides could be washed and cleaned of excess flesh. They were then dragged from the water and heavily salted. This was primarily the task of the women. Each day’s harvest was separately stacked, re-salted and re-stacked for a number of days, then dried, folded and transported to a river landing awaiting shipment by lugger to Darwin. Plates 3.3–3.5 show these stages of producing buffalo hides in the 1930s.
The lugger that picked up the hides also brought provisions for the shooting camps. They supplied not only work materials such as salt and ammunition, but a range of items for the personal consumption of the white shooter and his Aboriginal workers: clothes, knives, mosquito nets, cooking and eating utensils, flour, sugar, tea, tobacco, swag covers, rum etc. These were often supplied by the same agent that bought and re-sold the hides, and their cost was offset against the value of the hides consigned.

The number of Aborigines working in a buffalo camp varied. The major shooters, especially towards the end of the season when buffalo were concentrated in large numbers around limited bodies of water and production was at its peak, might employ around twenty people. There were, however, only a few Aboriginal men employed as shooters. Horseback shooting in particular was a skilled and dangerous business, and the few Aboriginal men who gained reputations for their ability were valuable to the white shooters. Those still living look back on their participation in this work with pride, and speak of their most successful runs and of dangerous encounters with the buffalo.
Aboriginal workers were paid principally in kind for their labour in the buffalo camps. The white boss made periodic distributions of food and other consumable goods from his stores, supplemented by new deliveries brought by lugger at intervals during the shooting season. Cash payments were rare before World War Two, but became more commonplace in the camps in later years. Valuable capital goods, such as guns and saddlery, remained the property of the white shooter, and were returned to him after use.
The largest distribution of goods was typically made at the end of the season, when the last shipment of cured hides had been loaded onto the lugger. Then extra quantities were either consumed in a loud and lengthy party, or taken bush to last some time into the wet season. During the wet, little work was available except for the few Aborigines who stayed at the main stations to repair fences and gear. Such places could, however, continue to act as distribution points for Aborigines who occasionally sought white foods to complement the primarily bush subsistence that they maintained during this period of the year.

Tobacco was the most valued commodity of all. In dealings with Aborigines, the whites of the region regarded it as a local currency, suitable for any transaction. Comments from Aborigines who worked in the camps during the years of the buffalo industry indicate that availability of tobacco was an essential precondition of their participation. Most favoured was the strong, dark tobacco called nikki-nikki. It was sweetened with molasses and sold as Sunlight tobacco in three inch sticks.
Both because of the constant mobility of the shooting camps and the white shooters' own lack of capital, living conditions during the shooting season were fairly uniform for all participants. The diet was the same, consisting of buffalo meat plus whatever else was available from time to time in the camp, and supplemented by bush foods from the surrounding country. Aboriginal women usually had sufficient time to forage locally in between processing hides in the morning and the arrival of fresh hides at the end of the day's shooting, and the white boss would often lend a rifle or shotgun to one of his workers to bring back geese or larger game. Everyone slept in swags in the open or under a bough shelter.

Although the attitudes and practices adopted by white buffalo shooters varied towards the running of their camps and their Aboriginal employees, the work was uniformly hard for both men and women. For the shooters, it was also dangerous. Descriptions of shooting include accounts of frequent falls and occasional injury or death from the horns of buffalo. The camps were often remote from medical help, and assistance took time to arrive.

Mining

The mining that had the greatest impact on the people of the Kakadu area took place some distance from it, in the hills surrounding the route of the north-south railway line between Adelaide River and Pine Creek, in the late nineteenth century. In successive rushes, large numbers of Europeans and even larger numbers of Chinese fossicked intensively for alluvial minerals and dug for shallow seams of gold.

Aboriginal labour was not needed here, but they were nevertheless attracted to the mining camps. Such sudden and intensive exposure to a concentrated non-Aboriginal population, and especially to their drugs and diseases, had a major impact on local Aboriginal groups, and contributed substantially to the depopulation of the Alligator Rivers region by the early years of this century. This, indeed, was the single most important effect of contact with non-Aboriginal culture. Occurring so quickly and so early, however, this phase of social history is beyond the range of living memory, and was not well-documented.

A revival of interest in mining in the 1930s produced little profitable work. However, at particular enterprises such as Moline and the Arnhem Land
Gold Mine at Yimalkba (Figure 3.2), Aborigines from the Kakadu area lived in fairly stable camps, establishing relationships of exchange and employment with the white workers (Plate 3.8). A tin deposit at Myra Falls, east of Oenpelli, also attracted the brief attention of a few people such as Yorky Bill Alderson and Tom Cole (Cole 1988, 299–312).

The last significant burst of mining activity in the Kakadu area, prior to the major developments of recent years, occurred in the upper South Alligator valley and the adjacent section of the Katherine River. There, in the 1950s, a series of small uranium mines were developed in the wake of the discovery at Rum Jungle a few years before. The remains of at least two of these open cuts, at Coronation Hill and Saddle Ridge (Figure 3.2 and Plate 3.6), are still visible from the road up the South Alligator valley. These mines ceased production in 1964 and employed no Aborigines.

PLATE 3.6 Remains of Saddle Ridge uranium mine, upper South Alligator River valley (Robert Levitus).
FIGURE 3.2 Some places of historical significance (compiled by Robert Levitus).
Oenpelli mission

Missionary work began in the Kakadu area in 1900, when a Northern Territory Native Industrial (Church of England) Mission was established at Kapalga on the lower South Alligator River. A newspaper article the following year reported an attendance of thirty to forty Aborigines, progress with buildings, stock and crops, and plans for an industrial farm. The missionaries found, however, that they required a more isolated site, such as an island, in order to have greater control and influence over their charges. The mission was relocated soon after, but apparently did not survive for long.

In 1925 another Church of England organisation, the Church Missionary Society, accepted an offer from the Northern Territory Administration to take over Oenpelli. Oenpelli had until 1922 operated as a dairy farm under Paddy Cahill. After many years of buffalo shooting around the East Alligator River, Cahill had established a station there which later became a Government farm.

During Cahill’s tenure, Oenpelli attracted a large number of local people, especially Gagudju-speakers. One of the pioneer ethnographers of Aboriginal Australia, Baldwin Spencer, visited Oenpelli in 1912 and with Cahill’s assistance recorded detailed material on Gagudju culture. But despite his knowledge of and close relations with these people, Cahill appeared helpless to reverse their rapidly dwindling numbers.

After Cahill’s departure in 1922 and a further two years under an interim caretaker, Oenpelli came under missionary supervision in 1925. After a difficult initial period, the missionaries embarked upon a gradual process of individual training and social engineering. Daily attendance at church was required, and the first baptisms were conducted on Easter Day, 1933. Around the same time, a policy of ‘every man his own home and garden area’ (Cole 1975) was introduced to promote a model of small-farming nuclear families, which made little progress before the war intervened.

The central institutions of the mission were church, school, dormitory and garden (Plate 3.7). Dormitories were used to separate the young from local camp life during the school week. They were always a controversial measure, even among other missionaries. Adults were encouraged to work regularly in mission enterprises. Notably, however,
there was no compulsion to remain on the mission, and reports show a marked decline in numbers during the dry season, when many people left for work in the buffalo camps to the west.

One of the most explosive issues in relations between missionaries and Aborigines was the availability of tobacco. The mission staff had always disliked having to use it as a form of payment, and finally, after some soul-searching, the Superintendent banned it from the beginning of 1940. Given the lack of ready alternative sources during wartime, this appears to have been a cause of great stress for many Aboriginal residents. The ban was interrupted by the arrival of soldiers, but reimposed after the war, until the NT Administration ordered that it be lifted. Most of the Oenpelli mission staff of the time declared themselves unable to participate in the distribution of tobacco, and resigned from the mission.

In its latter years Oenpelli benefited from larger government grants for training, health and education, as part of a wider Australian effort towards the assimilation of Aborigines. Its affairs were disrupted during
the final years of mission control, however, by serious alcohol problems at the Border Store, established on the other side of the East Alligator River, and by the first expressions of concern over the impact of uranium exploration on nearby sacred sites. In 1975, authority was formally transferred to an Aboriginal Town Council.

Cattle

When Europeans first turned their attention to the Alligator Rivers region in the late nineteenth century, they viewed it as promising cattle country. Early attempts to stock the area were soon abandoned. The failure of a major South Australian pastoralist, CB Fisher, to establish himself over a large part of the Top End including the Kakadu area, contributed to his bankruptcy and made clear the unsuitability of the coastal belt for cattle (Duncan 1967, 146). Two stations to the west of Kakadu – Marrakai and Glencoe – were among the first in the Northern Territory to be stocked with cattle, but by the 1890s they were of little importance, after their owners’ main interest shifted to Victoria River Downs.

After these initial efforts, cattle became a continuing, but secondary, concern in the northern part of the Alligator Rivers region (Figure 3.2). Paddy Cahill at Oenpelli and Fred Smith at Kapalga ran cattle and employed local Aboriginal stockmen. Other stations closer to the north-south railway line depended on an opportunistic mix of cattle raising, buffalo shooting, prospecting and dogging to make a living.

On Goodparla and Gimbat stations, in what is now Stage Three of Kakadu, pastoralists did attempt to make a living from cattle. George Cooke, who ran Goodparla from the early years of the century until the late 1930s, and Joe Callanan snr, who took up Gimbat in 1937, employed a small number of Mayali and Jawoyn-speaking people, and are still remembered by local Aborigines.

Goodparla lay along the track connecting Pine Creek to Oenpelli, one of the two main access routes to the Alligator Rivers region. Many current Park residents had some experience working for one or other of the post-war owners of the station. A number ventured further, working at times on stations to the south-west such as Esmerelda, Dorisvale or Claravale.

For some of these people, jobs such as mustering and droving brought their first experience of substantial lump-sum cash payments after a season's
work. Long droving trips also provided a few with experience of places well
beyond the Alligator Rivers region. One old man recalled bringing cattle
from Alice Springs to the Top End: 'I been down Alice Spring, I been down
everywhere. Aranda people reserve, I been down there. When I been
droving everywhere, you know' (Mingum, pers comm).

Other non-Aboriginal activities

A range of other small-scale operations engaged the attention of Aborigines
from the Park area, especially after World War Two. It is first necessary,
however, to mention the period of the war itself, locally known as 'Army
time'. In response to the threat of Japanese invasion, there occurred a large-
scale movement of troops and machinery to the Top End of the Northern
Territory, such that the non-Aboriginal population rose to unprecedented
levels and civil administration was suspended.

During this period, buffalo shooting was severely restricted due to lack
of ammunition, and the Army attempted to gather bush Aborigines
together in control camps. This period is remembered by some as one of
opportunity, when they were exposed to new work skills, military-style
organisation and facilities, and more generous treatment. A few
managed to remain in the bush, and a small number continued at
Oenpelli, but many were required for work around military camps
along the north-south road.

After the war, a new market for crocodile skins encouraged white shooters
to begin exploiting the large number of saltwater crocodiles in the lower
sections of the Top End's coastal rivers. Many of these men pursued this as
a sideline to buffalo shooting or prospecting. Frank Atkinson (Plate 3.8) was
one of the first to begin shooting in the Cooinda area.

Jim Jim waterhole and parts of the South Alligator was full of them.
You couldn't leave your horses there. You had to water your horses
and then take them two or three mile away from the waterhole and
that because the 'gators was known to grab 'em. Of an evening they
come out and they turn round facing the water ... A .303 bullet will go
into them anywhere. Doesn't matter how you hit 'em (pers comm).

Aboriginal bush skills proved particularly useful for hunting crocodiles.
By hiding in the grasses next to a billabong they could imitate the sound
of a wallaby's tail hitting the ground and attract crocodiles from the
other bank. By venturing out onto a waterhole on a barkraft they
could trace the movement of bubbles rising from a crocodile beneath and spear it, then follow its dying movements and retrieve it by means of a rope connected to the spear head. White shooters eventually developed their own method of night hunting from boats using head lamps and rifles. When crocodiles numbers fell and hunting was made illegal, they depended on speed and mobility to avoid detection, and Aboriginal participation fell away.

There was little commercial timber in the region, but stands of cypress pine (Callitris intratropica) and white gum (Eucalyptus spp.) were useful. The first sawmill in the area was operated by Chinese timber-getters at Nourlangie (Figure 3.2), probably before World War One. The Aboriginal name for the area around Nourlangie Camp, Anlarr, means cypress pine. Nourlangie
was again the site of a sawmill in the 1950s until the local stands of mature cypress pine were used up. This combination of a friendly European presence and the adjacent billabong system proved extremely attractive to the Aborigines of the region, and large numbers camped there during the life of the mill. Like Oenpelli some decades before, Nourlangie seemed to provide a focus for the penetration of the Kakadu area by neighbouring groups, this time from the east and south.

Within a few years of the collapse of the buffalo hides industry, a buffalo meat industry developed. Abattoirs operated at Oenpelli and Mudginberri. Although there was still a need for Aboriginal workers in these enterprises, they differed from the hides industry in that women were not involved, and there was not the same pattern of continuous and extensive movement through the bush. Moreover, the meat industry coincided with a general falling off in the level of Aboriginal participation in the workforce. Increased and more widely distributed cash income and easier access to alcohol reduced both the need to work and the reliability and efficiency of workers from the late 1960s.

The career of Fred Pocock illustrates the diverse activities from which a skilled and energetic bushman could earn a living in the post-war decades. Pocock operated a sawmill at Kekwick Springs, in the south of the Park, in the 1950s, before moving north to harvest crocodile hides from rivers and billabongs nearer the coast, followed by fishing and live catching of buffalo around the Wildman and West Alligator Rivers. The Daly River Aborigines he employed, though they remained with him for many years, did not establish any lasting attachment to the area.

Organised tourist facilities did not appear in the Park area until well after World War Two. They focussed on big game hunting and fishing, and attracted an international clientele. Nourlangie was turned into a safari camp after timber operations ceased, and Patonga and Muirella Park also catered for these early tour groups (Figure 3.2).

The level of tourism depended on road access. By the early 1970s there was a fairly good dirt road extending from Pine Creek to the turnoff to the El Sherana mine in the Gimbat area. A further track, built by the miners, extended from there to Jim Jim. Another bush track came into the Park area from the north-west, and road access was upgraded as far as the Mount Bundey iron ore mine in the 1960s.
In 1974 the Arnhem Highway was opened, and sealing of the road from Jabiru to Pine Creek, now known as the Kakadu Highway, began in the 1980s. This work should be completed by 1996. By the time of the Ranger Uranium Environmental Inquiry in the mid 1970s, it was plain that improved access was facilitating a rapid growth in tourism. Unlike the small organised groups catered for by the safari camps, this new wave of visitors brought their own transport, and created a need for planning and management to preserve the conservation values of the region.

3.3 Effects on Aboriginal life and society

Movement to the west

The permanent settlements at Darwin (known as Palmerston during its early period) and along the north-south railway line to Pine Creek proved attractive to Aboriginals, just as had the Macassan camps on the north Arnhem Land coast and Port Essington on the Cobourg Peninsula in earlier decades. By the 1930s, their effect was being felt as far east as Milingimbi in north-east Arnhem Land, from where groups of people were reported to have journeyed west seeking contact.

A report in the *Northern Territory Times* indicated that Aboriginals from the Kakadu area were visiting Darwin annually by 1882, thirteen years after its founding. A 1911 dry-season report on Aboriginal camps in the vicinity of Darwin included mention of a camp of Alligator Rivers people located half a mile north-east of town. It attributed the small numbers present to the employment of others in the town or on the buffalo plains.

On the other side of the buffalo country, Oenpelli in the early years of this century was a focus not only for the Mengerrrdji people who owned the area, but for people of various language groups – Gagudju, Urningangk, Erre, Amurdak and others – from both sides of the East Alligator River. Gunwinjgu people from further east had been in contact with Oenpelli and their movement towards it during Paddy Cahill’s tenure was documented by the anthropologist Spencer in 1912. These Gunwinjgu migrants negotiated their relationship with the existing local groups by means of ceremonial exchange and intermarriage.

The arrival of the Church Missionary Society at Oenpelli in 1925 stimulated a general western movement of Aboriginal groups. Two
particular trends can be identified. Members of local language groups previously attached to the station moved west to the buffalo camps and mining areas. Replacing them, the slow influx of Gunwinjgu-speaking people from the east accelerated, until by 1930 Gunwinjgu had become the dominant language at Oenpelli.

For many of these Oenpelli residents, as well as for the groups camped around Darwin and the mining camps, the Alligator Rivers area continued to exert an attraction. The seasonal buffalo hides camps offered the prospect of employment and access to more liberal quantities of European commodities, especially tobacco, than were available elsewhere. The natural environment too, especially the wetlands, attracted many people during the most productive seasonal phases (Plate 3.9). This attraction to the northern Kakadu area resumed after World War Two. A 1952 patrol officer's report recorded:

Towards the end of the wet season when goose eggs are plentiful I am told Wool Wonga Reserve is a favourite place for walkabout natives, some of whom cross the East Alligator River and come to this spot to collect their eggs...

Although most of the local buffalo shooters will say that very little use is made of it by the natives, one in their midst, Mr Harry Stott, a buffalo shooter of long standing in this country, told me he has seen, in recent years, a group of about fifty natives on their way to visit the Reserve. These natives called into his camp for tucker when he was shooting for Mr A. McGuire in the vicinity of the Goose Camp. They were from the country east of the East Alligator River and they told him their destination (Lovegrove 1952).

Population decline

By comparative analysis of the carrying capacity of similar sub-coastal environments, Keen has estimated that the area between the Adelaide and East Alligator Rivers supported an Aboriginal population of two thousand in pre-European times. By the 1980s, the number of people who could claim traditional attachment to this area, that is northern Kakadu and the area to its west, was about eighty (Keen 1980, 36–7), though the local population had long been supplemented by migration from other areas.

The concentrations of people encountered by Leichhardt on his route through the Kakadu area in 1845 testify to a very high population
density towards the end of the dry season. Here Leichhardt describes people he met with between the lower South and East Alligator Rivers.

They remained with us the whole afternoon; all the tribe and many visitors, in all about seventy persons, squatting down with crossed legs
in the narrow shades of the trunks of trees, and shifting their position as the sun advanced. Their wives were out in search of food; but many of their children were with them, which they duly introduced to us. They were fine, stout, well made men, with pleasing and intelligent countenances...

The natives visited us very early in the morning, with their wives and children, whom they introduced to us. There could not have been less than 200 of them present; they were all well made, active, generally well-looking, with an intelligent countenance: they had in fact all the characters of the coast blacks of a good country... (Leichhardt 1847, 505, 507).

The rapid and severe decline in population among Aborigines of the Alligator Rivers region from the late nineteenth century to the first decades of this century was the most disastrous single consequence of contact with non-Aborigines. The main cause of this fall in numbers was the spread of introduced diseases of which the Aboriginal population had no historical experience and to which they therefore possessed no resistance. These included leprosy, venereal diseases, tuberculosis, malaria, flu and measles.

In contrast, violence between Aborigines and non-Aborigines did not make a significant contribution. Although the historical records and available oral testimony recount individual acts of murder and revenge, there was nothing to compare with the sporadic warfare and massacres that characterised the pastoral colonisation of much of outback Australia.

Local people, however, sometimes refer to the level of violence among Alligator Rivers people themselves to explain their decline and especially the complete disappearance of certain groups associated with the swamp country. Disputes over women appear to have been common in traditional society, but contact with non-Aboriginal society may have introduced two further elements that exacerbated the level of inter-Aboriginal conflict.

The new patterns of migration that developed in response to the non-Aboriginal presence may have introduced tensions over territory, bringing into close proximity groups that previously had had little or no interaction. The high level of mortality from introduced disease may also have intensified conflict between Aborigines. The death of a relatively young person from sickness would, within the Aboriginal
scheme of the world, have presented itself as the result of another person's malevolence, effected through sorcery, and called for revenge. The frequency with which such deaths occurred during this period may therefore have generated a marked degree of suspicion and disunity within Aboriginal society. Moreover, the more dangerous technology now available, in the form of steel weapons and occasionally guns, meant that conflicts could more easily have fatal results.

Aboriginal adaptations

Archaeological, historical and oral evidence shows that the distinct change between wet and dry seasons in the Kakadu area was accompanied by Aboriginal movements between ecological zones. The major factor that governed this movement was distribution of food resources.

During the mid to late dry season, the wetlands and billabongs of the major rivers, especially the South Alligator, became a focus of Aboriginal attention, as people foraged and hunted for turtle, file snake and especially water birds such as magpie goose and brown duck (Plate 3.10). People living in the escarpment country were able to follow any of a number of creeks down onto the floodplain to their dry season camps. There, people of different clans joined in socialising, trading and organising ceremonies.

A series of camps was strategically located adjacent to the floodplains, providing points of access to the natural bounty of the wetlands for groups approaching from different directions. Population concentrations were higher here than at any other time of year. The occupation sites still visible in this area are extensive and rich in archaeological remains (see chapter 2).

When the first isolated storms of the wet season arrived, people moved out in various directions. Many travelled first to sandstone outliers that rose above the lowland forests, and then continued on towards the escarpment and stone country to make use of a series of caves. Their length of stay at each depended on the quality of shelter and local food resources, but also on the demands and pleasures of meeting with other groups for exchange and ceremony.
Robert Levitus

The buffalo industry did not interfere with this basic pattern of movement. It was a dry season industry that operated across the floodplains, and so provided an alternative mode of life for people who would ordinarily have occupied that area at that time of year. The shooting camps ceased operations before the onset of storms, and so freed Aboriginal workers to pursue their wet season priorities.

These wet season priorities, however, were probably the first to change. The existence of towns, the mission, and a few permanent stations in the buffalo country itself, offered new possibilities for wet season residence. At the end of 1900, police attempted to force non-local Aborigines camped around Darwin back to their own countries by burning their shelters. In protest, Paddy Cahill presented an Aboriginal perspective in the Northern Territory Times (4 Jan 1901):

Sir,
P’liceman bin talk ‘longa me ‘you clear out, go back longa your own country; Gubment bin tell you go your country, what for you no mor go; s’pose you no go away me burn ‘im all about house’. Me no more can go ‘longa country; jus’ now big pfeller rain come on, make ‘im wet all about, little boy no more can walk. White pfeller him bin come on ‘longa my country, me no more bin tel ‘im clear out, me bin let white pfeller stay ‘longa my country, shoot ‘im buffalo. Black pfeller work hard help ‘im white pfeller all time. S’pose black pfeller bin come ‘longa Port Darwin p’lice hunt ‘im ‘longa bush.

The existence of points of European residence probably affected the movements even of those who continued to revert to bush subsistence during the wet season. They could occasionally resort to such places to provision themselves with non-Aboriginal commodities until dry season employment recommenced.

In the post-war years, this expansive pattern of human movement seems to have been steadily curtailed by the provision of more extensive wet season residence and employment facilities, especially at government-funded institutions such as Oenpelli and Beswick. The collapse of the hides industry also caused a contraction in the pattern of dry season movements across the lowland areas. There was now a greater tendency to concentrate around fewer points of employment, encouraged by the introduction of welfare payments from a select number of outlets.

PLATE 3.11  Effects of salt-water incursion, west side of South Alligator floodplain, September 1981 (Robert Levitus).
The end of the hides industry and the correspondingly less expansive human presence on the wetlands allowed an unrestricted explosion of the buffalo population and the colonisation of new areas by large herds. The damage they caused to the lowland environment, only partially restored in recent years, reduced the extent and productivity of the fresh and slightly saline swamp domains (Plate 3.11). Local Aboriginal people recall some places on the South Alligator floodplain, now shallow depressions, to have once been deep freshwater billabongs.

More recently, the spread of the noxious South American weed mimosa (*Mimosa pigra*) from its point of first introduction on the Adelaide River floodplain, and the appearance of water weeds, especially salvinia (*Salvinia molesta*), which blanket the surface of open water bodies, have threatened to close off large areas of floodplain and river catchment to Aboriginal hunting. The balancing of weed control measures with maintenance of Aboriginal access to dry season bush foods is now presenting the Australian Nature Conservation Agency (ANCA) with a complex management problem (see chapter 8).

### 3.4 The status of the land

The historical processes surveyed above have been accompanied by dramatic changes in the legal status of the buffalo country and the Kakadu area. One of the earliest attempts by the NT Administration to address the problem of regulating the relationship between Aboriginal and non-Aboriginal society occurred in 1892, with the gazetting of a number of small reserves between the Adelaide and West Alligator Rivers. These were largely ineffective in their intended purpose of providing a separate and inviolable bush domain where Aborigines could pursue their own lifeways, partly because of the preference of those people for establishing contact with non-Aboriginal society, marked especially by their rapid integration into the buffalo industry.

The Arnhem Land Aboriginal Reserve, stretching from the East Alligator River to the Gulf of Carpentaria, was established in 1931, and incorporated the earlier mission reserve around Oenpelli. For Dr Cecil Cook, the Chief Protector of Aborigines, the purpose of the Arnhem Land Reserve was to keep Aborigines away from white settlements, satisfied and independent in their own country. He found the existence of missions such as Oenpelli in this area galling.
Missions almost universally demand that the mission area must be a native reserve. They neglect the detribalised aboriginal, devastated by disease, disrupted by the impact of white civilisation and lost in the new social order, and clamour for concessions in inviolable reserves, where they feel they will not be confronted with the insuperable difficulties obtaining in the vicinity of towns...

The process of social disruption, so loudly lamented and deplored by missionaries, where its effects are seen, is deliberately commenced by them in areas where otherwise the native organisation might remain intact for generations (Cook nd, 2).

In 1936, the original Woolwonga Reserve near the mining fields to the west was cancelled and a new reserve of the same name established on the South Alligator River wetlands. This later also became a wildlife sanctuary.

In 1976, with the passage of the Aboriginal Land Rights (Northern Territory) Act, the Arnhem Land and Woolwonga Reserves became Aboriginal freehold land. The Ranger Uranium Environmental Inquiry in 1977 proposed a land use package for the Alligator Rivers region that provided for the competing interests of Aborigines, miners, tourists and conservationists. A central recommendation was that a major national park should be established in the region, and that it should include a complete river catchment within its boundaries. The catchment selected for protection was that of the South Alligator.

This goal has been achieved in successive stages. In the initial steps taken pursuant to the Inquiry's recommendations, Stage One of Kakadu National Park was granted to local Aboriginal traditional owners and leased back by them to the Australian National Parks and Wildlife Service (now ANCA) to be managed as a National Park from 1979. In 1980–81, the Alligator Rivers Stage Two Land Claim succeeded in winning only a small portion of extra land for the claimants. The Stage Two area was declared part of Kakadu in 1984.

In 1987, the area formerly occupied by Gimbat and Goodparla pastoral stations was declared Stage Three of the Park, subject to a reservation of about one third of the area as a Conservation Zone, intended to provide for continued assessment of mineral resources before any final land-use decision was taken. The Conservation Zone was reduced to 47 square kilometres in 1989, and the Resource Assessment Commission asked by
the Federal Government to inquire into its resources. The central contest was over the deposits of gold, platinum and palladium located at Coronation Hill. In 1991, the Government decided to disallow mining and incorporate the Zone into Stage Three. The Jawoyn (Gimbat Area) Land Claim, originally lodged in 1987, was heard by the Aboriginal Land Commissioner in 1992 and his judgment is pending at the time of writing. The Land Claim over the Goodparla area has not been heard.

Coincident with the Ranger Inquiry and the initial transfer of ownership, there was a significant expansion of Aboriginal residence in the Park area. In 1980–81 the Gagudju Association was established to manage moneys payable to Aboriginal traditional owners from the Ranger Uranium Mine. The services of the Association have since been expanded to cover all Aboriginal camps in the northern part of the Park. By agreement with ANCA, a number of Aboriginal outstations have been established. In 1989, a Board of Management with an Aboriginal majority was elected to oversee Park management policy.

References


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4

The physical environment

Jeremy Russell-Smith, Stewart Needham & John Brock

4.1 Climate

The wet season is marked by localised, monsoonal depressions bringing heavy rain and tropical cyclones. Cyclones produce torrential rain, destructive winds, flooding and occasionally coastal storm-surges. For the 60-year period ending in 1975, at least nine cyclones have passed over the Alligator Rivers region, with another eleven passing close enough to have caused strong winds and storms (Hegerl et al. 1979). Mean annual rainfall for the region ranges from about 1300 mm in the south to 1565 mm in Jabiru (see Figure 4.1). Temperatures are high year round, with mean daily temperature variation from a maximum of 34.0°C to a minimum of 22.4°C (Figure 4.2). May to September are the coolest months. During the buildup to the wet season from October to December the combination of high temperature and humidity make for uncomfortable conditions. Humidity is highest from January to March, when cloud cover is highest (Figure 4.3). Annual potential evaporation exceeds rainfall in most years. It amounts to approximately 2400-2700 mm, with maximum monthly evaporation of about 260 mm in October and a minimum of about 100 mm in February when cloud cover is high.
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Fig 4.1 Mean monthly rainfall, Oenpelli (1957-1993) and Jabiru (1971-1994)

Note: Data for Jabiru derived from Jabiru East 1971-1989 and Jabiru Township 1990-1994

Source: Bureau of Meteorology Darwin

Mean annual total Oenpelli = 1470mm
Mean annual total Jabiru = 1460mm

Fig 4.2 Mean monthly maximum and minimum temperature, Oenpelli (1963-1993)

Source: Bureau of Meteorology Darwin
4.2 Hydrology

Drainage systems

The main drainage systems of the region begin with run-off from the plateau complex or start as springs at the foot of the escarpment. The broad rocky catchment of the plateau creates high run-off during the wet season, and sudden increases in stream flow are common. Streams typically form several sandy channels where they flow through the lowlands between the escarpment and the floodplains. All receive additional run-off from the lowland areas through which they pass.

Almost all of the region is drained by four rivers running north into the Van Diemen Gulf, except for small areas in the far south and south-west which are in the Katherine and Mary catchments. The four rivers consist of distinctly different stages along their passage to the sea. The two largest rivers, the East and South Alligator Rivers, rise in the sandstone
The physical environment

plateau country, and so their upper reaches typically follow narrow and deep clefts in the sandstone which are formed by vertical cracks or joints in the rock.

After the rivers leave the plateau country and adjacent hills, and enter the low sandy plains which cover most of Kakadu, they broaden out into the next distinct stage of braided alluvial channels. There are often four or more channels separated by banks of loose sand which are often breached and reformed in times of high flood. The channels of these creeks, such as the Magela, Nourlangie, Jim Jim and Barramundie Creeks, are not continuous across the floodplains to the major rivers; instead, they divide and distribute their water widely over the third river stage, the expansive floodplains. These act like a large retarding basin, storing the water up over the wet season and gradually releasing it. Broad areas are flooded for between three to nine months, depending on location and seasonal rainfall. Flow from the creeks is supplemented by heavy local rain and runoff from the surrounding sandy lowlands. By the end of the dry season 95% of the floodplains are dried up, leaving isolated deep billabongs such as Yellow Water.

The final stage of river development is the estuary – a relatively narrow tidal channel reaching in from the seas which cuts through the floodplains. The longest example is the estuarine section of the South Alligator River, which at the Arnhem Highway bridge crossing is still 50 km from the sea. The estuarine channel banks are formed by silty levee banks, often marked by a narrow ribbon of mangroves and monsoon rainforest trees in the otherwise mostly treeless floodplains.

The Wildman and West Alligator Rivers in the west of the Park are relatively small rivers. They rise in sandy lowlands and lack the headwater characteristics of the larger rivers.

Dry season water regime

At the onset of the dry season, most streams decline and eventually cease to flow except in the upper reaches fed by springs or seepage, and the lower tidal sections of the main rivers. The downstream reaches typically break up into disconnected billabongs along the main channel and adjacent backwater lagoons. The flooded plains slowly drain – the higher parts drying to cracked clay pans, the lower sections retaining water in swamps and billabongs.
The amount of water and the number of waterbodies which persist during the dry season vary markedly from year to year, depending on the length and intensity of the wet season. Some of the lowland water bodies persist until the next wet season, as do some rock pools in the plateau region. Consequently they are critical to the survival from year to year of many animals and plants, and in the past were major controls on the Aboriginal way of life.

Stream flows

Stream flow data are recorded by the Northern Territory Power and Water Authority at gauging stations throughout the region. Total annual and mean monthly discharges for one gauging station on the Magela system are shown in Figures 4.4 and 4.5.

Wet season rainfall patterns cause large variations in the hydrological regime. Wet season stream flows comprise a series of peak flows superimposed on a base flow which usually begins in about mid-December and ceases about the end of June. In a very wet year, flow may commence in November and finish in August. The estimated total annual flows at the mouths of the South and East Alligator Rivers are 2370 and 2560 million cubic metres respectively; estimated average annual flows for Magela and Nourlangie Creek systems are 244.5 and 678.8 million cubic metres respectively (Christian & Aldrick 1977).

Groundwater

Underground water may be stored in joints or cracks in the basement rock; in porous limestone rock which can hold large quantities of water; and in shallow aquifers in weathered rock, old sand and sandstone deposits and sand along stream channels.

Accumulations of water in faults in the basement rock have been the main source of pastoral water supplies in the past. Water quality in many of these aquifers is good, suggesting local surface recharge. The highest yielding aquifers so far found are associated with the limestone. Groundwater is currently the prime source of potable water. The bulk of Jabiru town water comes from bores in the Park.
The physical environment

Fig 4.4 Annual discharge of Magela Creek at Gauging Station GS821009

Notes: 1GL = 1 GigaLitre = 1 x 10^9 litres

Source: Environmental Research Institute of the Supervising Scientist

Fig 4.5 Monthly flow of Magela Creek at Gauging Station GS821009

Notes: 1GL = 1 GigaLitre = 1 x 10^9 litres

Source: Environmental Research Institute of the Supervising Scientist
Water quality

The quality of water and the sediments carried by it are determined by the source. If the water has percolated through rock before emerging as springs it is likely to be harder, and depending on what rock it has infiltrated it may be relatively high in heavy metals and radioactivity. If it has entered the stream as surface run-off it is more likely to be soft, low in heavy metals and low in radioactivity, unless it has passed over a radioactive deposit. In the wet season the waters of most streams are soft, slightly acidic, low in heavy metals, low in radioactivity and have low buffering capacity.

The quality of the confined water bodies deteriorates once flow has ceased (Morley et al. 1985a). Deeper water bodies with steep banks and sandy bottoms tend to remain cooler, clearer and of higher water quality; changes are more pronounced in the shallower billabongs which have bottoms of silty material with high exchange capacities. Increases in heavy metals, uranium and radium content may occur, hardness values may increase, and turbidity increases, especially in billabongs used by geese or feral animals such as pigs or buffalo. Water temperature rises and may reach over 40°C with a consequent decrease in dissolved oxygen. Thus changes in water quality during the dry season impose stress on aquatic organisms through high temperatures, low oxygen levels, high turbidities, shifts in ionic composition and pH, and increased concentrations of potentially toxic heavy metals.

The first rains of the wet season begin the flooding of the wetlands and flush the billabongs, restoring good water quality. However, in the transitional period, especially if the first flushing is weak, increased stress can occur to aquatic life. The first water to flow down and across the floodplains is characteristically quite acidic due to dissolution of groundwater salts that have collected on the soil surface during the dry, and can briefly lower the pH in the billabongs below 4. This is sufficient to stress, and sometimes kill, large numbers of fish (Morley et al. 1985, Hart et al. 1987); the actual toxic agent is believed to be aluminium, which is mobilised under low pH conditions. Further flow improves water quality and relieves the stress to aquatic life. Fish stocks are rapidly replenished, both from the billabong populations and from populations that survive the dry season in refuge pools in the headwaters and which migrate down onto the floodplains.
Water management

The stability of the wetlands and survival of the organisms they support depend on the maintenance of water quality. In response to pollution and environmental damage caused by buffalo and pigs, feral animal control, combined with the construction of retention levees, has improved the water quality and general habitat of many billabongs.

Uranium deposits occur in the catchments of Magela Creek, Nourlangie Creek, Cooper Creek and in the headwaters of the South Alligator River near El Sherana. The presence of the Ranger Uranium Mine, situated in a Project area of about 83 km² containing a 28.7 km² Special Mineral Lease which forms an enclave within the Park boundaries, creates a potential source of water pollution. Uranium mines within the Alligator Rivers Region are regulated under the laws of the Northern Territory. The Office of the Supervising Scientist (OSS), part of the Commonwealth's Environment Protection Agency (EPA), exercises a supervisory and research role. The OSS (through the Environmental Research Institute of the Supervising Scientist) conducts research into effects on biological organisms of possible water contamination (eg Holdway 1989; Humphrey et al. 1990), and into the effect of mining activities on the upper reaches of the South Alligator River.

4.3 Geology, landforms and soils

The physical landscape comprises features of great antiquity, as well as modern, dynamic landforms. As an example of the former, the sheer cliffs of the western Arnhem Land escarpment record a sedimentary history dating back 1700 million years; and these are not the oldest exposed geological features occurring in the region. Such antiquity reflects the marked tectonic stability of the Top End region. As a result of this stability the rocks of the region have been deeply weathered for many millions of years to form strongly leached and infertile soils. This, together with development in the Late Tertiary of a climatic regime characterised by marked rainfall seasonality, has markedly influenced the development of the flora and fauna of the region.

In contrast, the extensive coastal and riverine alluvial plains are of recent origin, often no more than a few thousand years old. These modern landforms owe their genesis to the deposition of sediments in drowned
river valleys associated with the stabilisation of sea level at about its present level some 6000 years ago. Therefore, the deeper saline sediments underlying the floodplains are overlain by brackish, organic-rich, acidic soils which support the freshwater wetlands.

The oldest rocks, which lie beneath and pre-date the 1700 million year old sandstone of the Arnhem Land plateau, form part of what is known as the Pine Creek Geosyncline. A geosyncline is a large geological depression filled with a thick sequence of sediments and volcanic rocks, which is later subject to orogenesis (mountain building). In this process the rocks are folded, metamorphosed, and intruded with granite, dolerite, and other igneous rocks. The rocks of the Kakadu region originated as sandstone, siltstone, shale, conglomerate limestone and evaporites deposited by rivers and in shallow seas in the eastern part of the geosyncline, but during orogenesis were transformed into schist, gneiss, quartzite and marble.

The Pine Creek Geosyncline is a highly mineralised geological province (mainly gold), and as a consequence has been the subject of extensive exploration and research. The Kakadu region is noted for its high-grade uranium deposits. Uranium (with some gold) was mined from 13 small deposits in the South Alligator River Valley area in the south of the region in the 1950s; the Nabarlek deposit was mined out and stockpiled in 1979 and ore treated until 1988; and mining, begun at Ranger in 1980, continues to the present. The full endowment of mineral deposits in the region is unknown as a result of restrictions on mineral exploration and development in the Park. Exploration has continued in some areas in the east of the region in Arnhem Land, but to date no economically viable deposits additional to Nabarlek have been found. Many of the research results related to geology and mineralisation are summarised in Ferguson and Goleby (1980).

In relation to younger rocks and sedimentary sequences which overlie the Pine Creek Geosyncline, Williams (1969a,b; 1991) and Galloway (1976) have described the geological and geomorphological processes, particularly weathering associated with lateritic landforms. Late Quaternary processes, especially those concerning riverine floodplain evolution, are covered by Hope et al. (1985), numerous papers by Woodroffe and his colleagues (eg Woodroffe et al. 1985a,b,c, 1986, 1987; Chappell 1988; Woodroffe 1988), and Clark and Guppy (1988). Soils are considered in detail by Hooper (1969) and Aldrick (1976).
Two dating conventions are used in the following account: Ma (million years ago) and BP (years before the present).

The geological record: formation of the Pine Creek Geosyncline to the Cretaceous sea (2500–110 Ma)

Landscape features in Kakadu National Park record over 2000 million years of geological evolutionary history. The regional basement rocks are late Archaean granites and gneiss of the Nanambu Complex, which have been dated to 2470 Ma (Page et al. 1980). These rocks underlie most of the area between the South and East Alligator Rivers north of Cooinda, but are poorly exposed mostly as small bare domes at the edge of the floodplains. An excellent exposure of granite, 4 km south of Jabiru, preserves the ancient weathered profile within the granite. From about 2400 Ma a deep trough developed, possibly as a result of rifting and subsidence of the granite basement (Stuart-Smith et al. 1980). This trough, the Pine Creek Geosyncline, is the main geological structure of the region and covers at least 66 000 km² between Darwin in the west, Pine Creek to the south, and Milingimbi in the east.

Between 2400–1870 Ma this structure gradually sagged down, allowing the deposition of at least 14 km of sediments and interbedded volcanics during the Early Proterozoic period (Needham et al. 1980). A number of sedimentary units are recognised which essentially reflect alternating deposition in fluvialite (sand) and shallow marine to supratidal (clay, carbonate) environments. One of these units, the Cahill Formation, contains the uranium deposits of the Alligator Rivers Region (Needham 1988).

At some time after 1900 Ma a localised episode of orogenesis heralded regional metamorphic activity in which the geosynclinal sediments, volcanics, and some basement granites were folded, faulted and metamorphosed under extreme heat and pressure. Some rocks were so strongly affected that they were partly melted to form migmatite, a granite-like rock. The end of this episode is dated at 1800 Ma in metamorphosed rocks throughout the Pine Creek Geosyncline (Page et al. 1980), and numerous granites were intruded about this time. Subsequent subsidiary episodes of igneous and orogenic activity continued until 1690 Ma, culminating with the intrusion of a 22 000 km² sheet of dolerite up to 250 metres thick (Oenpelli Dolerite), which outcrops in small areas of the Arnhem Land plateau. Thereafter, the
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<td>Tertiary</td>
<td>Landscape similar to present day</td>
</tr>
<tr>
<td></td>
<td>Small fault-bounded basin of terrestrial sand deposits</td>
</tr>
<tr>
<td></td>
<td>local faulting in south</td>
</tr>
<tr>
<td>Mesozoic</td>
<td>Shallow sea covers north and west of region</td>
</tr>
<tr>
<td>100 Ma</td>
<td>Table-land siltstone and sandstone (and buried sequences near coast), marine and terrestrial sediments (Bathurst Island formation)</td>
</tr>
<tr>
<td>Early</td>
<td>Dolerite intruded 1-2km deep</td>
</tr>
<tr>
<td>Proterozoic</td>
<td>Younger dolerite (Oenpelli Dolerite) intruded as undulating sheets cutting across the folded metamorphic rocks and cutting Kombolgie Formation sandstone</td>
</tr>
<tr>
<td>1690 Ma</td>
<td>Plateau-forming sandstone and basalt (Kombolgie Formation) deposited as braided alluvial fan and fissure-fed lavas</td>
</tr>
<tr>
<td></td>
<td>unconformity: 1-2km erosion; marine transgression forms sea cliffs</td>
</tr>
<tr>
<td></td>
<td>Broad alluvial fan spreads across region from a northern hinterland</td>
</tr>
<tr>
<td>1700 Ma</td>
<td>unconformity: gentle folding; erosion forms wide peneplain; deep weathering</td>
</tr>
<tr>
<td></td>
<td>Volcanic rocks - ignimbrite, tuff, rhyolite, basalt, interbedded sandstone (include Puf Puf Rhyolite, Coronation Sandstone, Plum Tree Creek Volcanics)</td>
</tr>
<tr>
<td></td>
<td>unconformity: several km of erosion; rift faulting</td>
</tr>
<tr>
<td></td>
<td>Younger granites (Jim Jim and Malone Creek Granites)</td>
</tr>
<tr>
<td></td>
<td>folding, metamorphism, igneous intrusions, faulting</td>
</tr>
<tr>
<td></td>
<td>Metamorphic rocks - schist, gneiss, quartzite, marble, amphibolite (Cahill Formation, Nourtange Schist)</td>
</tr>
<tr>
<td></td>
<td>Older dolerite (Zamu Dolerite) intruded as sheets parallel to bedding and before folding</td>
</tr>
<tr>
<td>1860-1830 Ma</td>
<td>Weakly metamorphosed sedimentary rocks</td>
</tr>
<tr>
<td></td>
<td>Sandstone, quartzite (mainly Mundogie Sandstone), alluvial fan deposits</td>
</tr>
<tr>
<td></td>
<td>Siltstone, shale, sandstone, limestone (includes Masson Formation, Wildman Siltstone, Koopin Formation), shallow marine and intertidal sediments</td>
</tr>
<tr>
<td>2500 Ma</td>
<td>unconformity: several km of erosion</td>
</tr>
<tr>
<td>Archeean</td>
<td>Older granite, gneiss (Nanambu Complex)</td>
</tr>
</tbody>
</table>
Figure 4.6 Generalised geology of Kakadu National Park. Compiled by RS Needham from Australian Geological Survey Organisation data.
PLATE 4.1 To the east, the Kakadu landscape is dominated by the towering sandstone scarps of the Arnhem Land plateau. To the west, the lowland landscape is more subdued, comprising a deeply weathered surface incised by seasonal creeks and tidal rivers (Jean-Paul Ferrero/AUSCAPE).

PLATE 4.2 Seasonal streams and deep rock pools are a striking feature of the Arnhem Land plateau such as at Koolpin Gorge in the southern sector of Kakadu (Peter Jarver/Wildlight Photo Agency).
PLATE 4.3 The major rock-type of the Arnhem Land plateau is sandstone of the Kombolgie Formation. The cross-bedded layering of the sandstone illustrates that it was deposited originally in a fluviatile (riverine) environment (Jeremy Russell-Smith).

PLATE 4.4 Ripple marks are commonly preserved in the Kombolgie Formation sandstone and are further evidence of its fluviatile and shallow-water deposition (Stewart Needham).
PLATE 4.5 The 'big wet', when riverine floodplains are inundated by sheets of water metres deep and for months at a time (Jeremy Russell-Smith).

PLATE 4.6 By the end of the dry season, permanent fresh water on the floodplains is restricted to chains of billabongs, and extensive areas dry out to reveal bare cracking black-soil plain (Greg Miles).
The physical environment

region appears to have been tectonically stable, apart from relatively minor events associated with localised igneous intrusions of phonolites, dolerites and basalts which occurred at various times through the Middle Proterozoic and Early Palaeozoic (Page et al. 1980).

During the latter stages of this tectonic and orogenic activity, the land surface was eroded back to a gently undulating plane, generally with a local relief of 20 m or so, but including isolated hills and ridges up to 250 m in elevation (Needham 1988); a surface not unlike that between Darwin and Jabiru.

Subsequent to this period of planation, at least several hundred metres of Middle Proterozoic sands, gravels and intercalated lavas were laid down, more or less horizontally, across the earlier erosion surface. This sedimentary formation, the Kombolgie Formation, survives as the Arnhem Land plateau; its massive sedimentary layers and minor basaltic lenses clearly exposed in the retreating escarpment. Exploration drilling has recently shown that these rocks are intruded by the 1690 Ma old Oenpelli dolerite and that they are therefore older, suggesting an age of deposition about 1700 Ma.

The next regional event in the geological record does not occur until 1500 Ma later, in the Late Jurassic–Early Cretaceous. Over this immense interval it is likely that more sediments were deposited on top of the Kombolgie Formation, but that these and some of the older rocks were removed by erosion, leaving no trace of their former existence, only a deeply weathered landscape of low relief (Hays 1967; Williams 1969b; Galloway 1976).

In the Kakadu region marine sediments of the Bathurst Island Formation (Hughes 1978) underlie the northern parts of the lowland sandy plains, and terrestrial sediments of the Petrel Formation form isolated mesas on the Arnhem Land plateau, both suggesting that the Arnhem Land escarpment is an ancient feature which formed a shoreline, possibly even sea-cliffs, as long ago as 150 Ma (Needham 1988). Such a view is in contrast to other contemporary opinion which holds that the Arnhem Land plateau was inundated under a shallow sea in the Late Cretaceous (e.g. Veevers 1984; Williams 1991). Fossils are rare and poorly preserved, however, and no direct evidence for the submersion of the plateau exists. Skwarko (1966) reported Syncyclonema territoraneum (a pelecypod) and several other indeterminate pelecypods and plant
fragments from the extreme south of the region. Internal ammonite casts and palm tree logs occur in cliffs near the Mary River Ranger Station. The spread of the Late Cretaceous seas across the region was part of an extensive marine transgression which covered much of northern Australia (Skwarko 1966), associated with the collapse of continental margins due to rifting of India from the then super-continent Gondwanaland (Veever 1984; Williams 1991).

**Formation of the modern day landscape: Cainozoic erosion and deposition (110 Ma–Present)**

After the withdrawal of the Late Cretaceous sea, the region remained tectonically stable and of low relief for possibly a further 80 Ma or so. Over this period the Mesozoic sediments were deeply weathered and leached, resulting in a regional land surface, equivalent to the Bradshaw surface of Wright (1963) and the Tennant Creek surface of Hays (1967). Today this surface is recognised as capping elevated fragments of the Arnhem Land plateau, and other elevated landforms over extensive areas to the south of the Park.

In the Miocene, essentially between 25–10 Ma, a new phase of erosion commenced as a consequence of prolonged, slow tectonic uplift of the land surface and concomitant rejuvenation of riverine systems. As a result most of the Mesozoic rocks and their deeply weathered Tertiary surface were stripped away, exposing older, more resistant rocks.

Galloway (1976) comments that resistant sandstone elements of the northern Arnhem Land escarpment have scarcely changed position as a consequence of this erosion but, in the south, scarps have retreated as much as 25 km. These imposing scarps and rugged plateaux with their deeply incised valleys and gorges comprise the dominant landform feature of the Park.

Associated with this removal of the deeply weathered Tertiary surface and Kombolgie sandstone cover was the exposure of the ancient, Early Proterozoic metamorphosed sediments, igneous and plutonic intrusions, and rift volcanics. Today these resistant ridges, hills and associated valleys form a major landform in the south-west of Kakadu National Park, comprising the Dissected Foothills of Williams (1969b), or the Southern Hills and Basins unit of Christian and Aldrick (1977).
Also at this time, rivers draining these upland areas deposited their sedimentary loads in the valleys and basins of the recently exhumed northern plains. In time the valleys filled and low resistant ridges were progressively bevelled and buried, forming a broad depositional apron, the Koolpinyah Surface, which today comprises the gently undulating lowlands which stretch from Darwin to Kakadu, and on into Arnhem Land (Christian & Stewart 1953; Hays 1967; Williams 1969a,b, 1991).

By the start of the Quaternary period, approximately 2 Ma ago, three of the four major landforms of the Park were already well developed: the sandstone Arnhem Land escarpment and plateau, and associated outliers; the southern hills and basins comprising exhumed Early Proterozoic metamorphosed rocks and intrusions; and the lowland plains and incised river systems of the Koolpinyah Surface. The fourth major landform comprises the geologically recent development of extensive coastal riverine plains. These plains have formed (and are still forming) by sedimentary infilling of drowned river valleys after the oceans attained their modern level about 6000 BP. Each of these four major landform features is considered below in turn.

**Major landforms and soils of Kakadu National Park**

*Arnhem Land plateau and escarpment complex:* The Park includes the western rim of this mostly inaccessible plateau with its sheer escarpments, waterfalls, overhangs and caves. The eastern boundary of the Park follows the escarpment rim north of Jim Jim Falls. South of these falls the Park takes in a westward projecting sandstone promontory which is incised by the north-west tending valley of the South Alligator River. South again, the Park takes in the western rim and escarpment of the Bulademo Tableland (or Marraval Plateau). Also included in this Complex are a number of outlying sandstone residual massifs (eg Nourlangie Rock, Mt Brockman) which rise above the surrounding low-lying plains.

The Arnhem Land escarpment is the most striking scenic feature of the region and rises up to 330 m above the plains. It is formed by quartz sandstone of the Kombolgie Formation which unconformably overlies older rocks. Where these underlying rocks are weak, the sandstone is undermined and eventually collapses to form sheer cliffs.

As discussed in detail by Galloway (1976) the stability of the scarp is largely determined by the degree of exposure of the weaker underlying
rocks. Stable scarps, recognised by their generally rounded forms, are those where the underlying rocks are mantled by debris, or where sandstone beds dip, or are down-faulted, below the local base-level of erosion. With prolonged stability the scarp itself is worn away until it is no longer recognisable. Active scarps in Kakadu National Park occur mostly along the main escarpment face south to Jim Jim Falls, and then westward to Graveside Gorge. Needham (1992a,b) describes how silicification of the sandstone along vertical joints ‘case hardens’ the rock, and that when such surfaces are exposed by scarp retreat, how they form very stable sheer faces suitable for rock painting.

On the plateau itself the stripping away of most of the Late Cretaceous cover rocks has exhumed a rugged landscape comprising resistant, flat-bedded quartzose sandstones, criss-crossed by tensional joints, faults and dolerite dykes which have been deeply weathered into a maze of narrow valleys and gorges. Much of the plateau occurs at elevations above 200 m, the highest point being Kub-o-wer Hill (570 m), outside and just to the east of Kakadu.

Soils are absent from extensive areas of the plateau, the surface being formed by bare pavements and sandstone outcrops (Hooper 1969; Aldrick 1976). Where developed, soils amount to skeletal veneers of sand seldom more than 150 cm deep. Deep sand plains are developed in sedimentary basins in a few situations on plateau summits, and are thought to be derived from erosion of Cretaceous sediments (Needham 1988). One such extensive sand plain in the far south of the Park forms the surface of the Bulademo Tableland. The plateau there comprises a largely featureless surface without an integrated stream network; largely because the Cretaceous rocks are permeable, homogeneous, and lack the joint, fault and dyke structures which lace the Arnhem Land plateau; as such, the plain acts as a major aquifer. The South Alligator and Mary Rivers rise as springs fed from this aquifer. As well, the surface contains large sub-circular depressions which are likely to be solutional dolines in underlying laterised sediments (A Young & B Wood (CCNT) pers comm). Twidale (1987) describes similar dolines in Mesozoic rocks of the Sturt Plateau further to the south.

**Southern hills and basins:** These hills and associated valleys occur mostly in the south of Kakadu National Park where they have been exhumed from beneath the retreating Arnhem Land escarpment.
FIGURE 4.7 Landforms of Kakadu National Park.
Significant areas in Kakadu include the upper valley of the South Alligator River, the Mount Partridge Range, and west and north-west of the Bulademo Tableland. They have been formed by the stripping away of overlying deeply weathered Late Cretaceous sediments and other cover rocks to reveal an ancient landscape of Early Proterozoic metamorphic sediments, igneous and volcanic rocks. As such, the hills form a modern day erosional surface comprising a sequence of rocky strike ridges (ie running parallel to the geological grain of the rocks) flanked by narrow talus slopes or pediments, separated from each other by alluvial flats of variable width (Williams 1969b; Galloway 1976).

Soils formed on doleritic, volcanic or weathered metamorphic rock exposures are predominantly clays or loams. Soils formed on granites are typically gritty, coarse-grained sands. On slopes of more than 5 degrees the soils are mostly skeletal (Aldrick 1976).

**Koolpinyah surface**: This surface comprises the gently undulating lowland plains which stretch from Darwin to the Arnhem Land escarpment. From the southern hills and basins, the lowland plains slope gently northwards to the sea along a gradient of 1:1000. The surface is primarily a Late Tertiary depositional surface, consisting of sediments derived from erosion of Mesozoic sediments and earlier cover rocks. Borehole data indicate that the sediment mantle is seldom more than 30–40 m in depth. Resistant ancient rocks outcrop as low strike ridges or hills in various places (Williams 1969a).

As outlined by Hays (1967) and Williams (1969b, 1991) the Koolpinyah Surface comprises a complex of gravels, sands, silts and clays which has been repeatedly weathered, eroded, redeposited and reweathered. Intense chemical weathering has occurred as a result of sediments being alternately oxidised and saturated. Such weathering has involved the leaching of bases and alkali earths from surface sediments, leaving only residual concentrations of partially hydrated oxides of iron and aluminium.

Where such concentrations of iron have been precipitated to form small nodules, or nodules have been cemented together subsequently to form extensive sheets, the resulting ironstones generally are referred to as laterite. The ironstones commonly form broken pavements 60 cm thick which commonly outcrop on the plains, especially around the headwaters of creeks. The thick profile of strongly leached rocks
beneath the ironstone is exposed as a mottled yellow-brown material in many of the road cuttings along the Kakadu Highway north of Cooinda. Laterites are actively forming in many low-lying areas associated with seasonally high watertables. Elsewhere on the Koolpinyah Surface a mass of lateritic detrital material such as pea-sized pisoliths is incorporated in the soil, indicating extensive past weathering, erosion and transport of sediments.

It should be noted, however, that the accumulation of iron at the surface is but one product of the laterisation process, and other, deeper zones of accumulation are recognised for different weathering products. Collectively, these zones constitute the standard lateritic profile. For detailed accounts of laterite formation the interested reader is referred to Williams (1969b), Paton and Williams (1972), and McFarlane (1983).

As a consequence of this leaching and the concomitant accumulation of iron and aluminium ions in surface horizons, soils are acidic and infertile. At the top of the catenary (ie topographic) sequence, soils are typically uniform to gradational deep, well-drained red sands and sandy loams with minor areas of loams or gravelly, shallow deposits. With increasing slope laterite outcrops are common, and soils predominantly comprise gradational, yellowish sandy loams, often exhibiting poor drainage. On lower slopes lag (coarse residual and sorted material) deposits vary from deep sands in depressions between interfluves, to shallow sandy mantles over clays in alluvial situations (Hooper 1969; Aldrick 1976).

While the undulating lateritic plains constitute the major landform type of the Koolpinyah Surface, two other features are of importance. The first concerns the occurrence of large numbers of circular to sub-circular solutional dolines (sinkholes), many of which form seasonal or permanent waterbodies. These are formed by solutional collapse of underlying rock strata, and are particularly well developed west of the South Alligator River over a sequence of massive magnesian limestone (dolostone) in the Early Proterozoic Cahill Formation (Needham 1988).

The second feature concerns the incision of large, essentially north-flowing river systems. In Kakadu these rivers include the Mary, Wildman, West Alligator, South Alligator (including Nourlangie and Jim Jim Creeks), and the East Alligator (including Magela Creek). At the peak of the wet season, usually between January and March, these rivers are deep and fast-flowing.
In their freshwater reaches they often dry out into a string of waterholes and billabongs by the end of the dry season. The alluvial plains and levees associated with these rivers comprise mostly sandy deposits where they drain sandstone formations of the western Arnhem Land escarpment. Elsewhere the alluvial deposits are more silt- and clay-rich where streams drain the exhumed, dissected foothills.

Coastal riverine plains: Such plains are associated with the tidal reaches of all major river systems in Kakadu National Park. They are recent, estuarine-deltaic depositional landforms which are still actively evolving, especially in coastal situations. Wasson (1992) reports a steady rate of sedimentary aggradation over the Magela floodplain of about 0.2 mm per year. Following Woodroffe et al. (1986) the coastal riverine plains comprise three broad units (Figure 4.8).

The Coastal Plains comprise saline to hypersaline clays and mudflats and occur as littoral fringes at the mouths of tidal rivers and creeks. As well, shelly beach ridges, or cheniers, have been thrown up by storms on some coastal plains in the region. Elsewhere smaller tidally inundated areas are intermittently associated with main river channels and are included by Woodroffe et al. (1985a) in their second unit, the Deltaic-Estuarine System.

This system consists mostly of floodplain with black, organic cracking clays which overlie estuarine deposits at shallow depth. Most areas are flooded for up to four months each wet season. Lower lying areas on the plains include landward fringing backwater swamps which may be inundated for up to nine months, and semi-permanent billabongs and former river palaeochannels. The third unit, the Alluvial Plains, comprises freshwater (fluvial) floodplains formed at the outflow junction between floodplain estuarine sediments and upland river systems entering from the Koolpinyah Surface. In these situations fluvial systems do not connect with tidal systems by a direct channel but, rather, via multiple unconnected channels in broad seasonally flooded basins. Examples in the Park include the Magela, Nourlangie, Jim Jim and South Alligator systems. The coarser water-borne sediments are deposited as the waters flowing from the upper reaches of the rivers encounter the slack waters of the floodplains, in some cases forming delta-like features; for example, on the South Alligator river 7 km west of Cooinda.
FIGURE 4.8 Block diagrams summarising morphologic and stratigraphic relationships in the estuarine funnel, sinuous meandering, cuspate meandering and upstream segments of the South Alligator River (Woodroffe et al. 1986, 112).
The formation of the coastal riverine plains dates to the terminal phases of the last rise in sea level which accompanied the melting of northern and southern hemisphere icecaps. This rise in global sea level began about 14 000 BP when it was approximately 150 m below today's level (Chappell 1983). At that time the northern continental shelf was exposed; the coastline was some 300 km north of its present locality; Australia and New Guinea were one land mass; and the Gulf of Carpentaria was reduced to an enclosed saline basin ('Lake Carpentaria') cut off from the sea (Torgersen et al. 1988).

Sea level rose until about 6800 BP when the sea level in northern Australia stabilised within 5 m of the present level (Woodroffe et al. 1987). Sea level rise caused the drowning of former river valleys, and their subsequent infilling with estuarine sediments. Many detailed investigations have been undertaken of the geomorphological and vegetation development associated with the drowning of the South Alligator River and Magela Creek systems in Kakadu National Park (eg Hope et al. 1985; Woodroffe et al. 1985a,b,c, 1986, 1987; Chappell & Grindrod 1985; Chappell & Woodroffe 1985; Chappell 1988; Clark & Guppy 1988; Woodroffe 1988; Wasson 1992).

A number of phases are evident in the development of the modern coastal riverine plain of the South Alligator system (Woodroffe et al. 1985a,b,c, 1986). The transgressive phase involved the marine drowning of the South Alligator valley for 100 km inland from the present coast, and establishment of mangroves along the developing shoreline. Between 6800–5300 BP widespread mangrove development occurred as the rise in sea level decelerated and stabilised. This, the 'Big Swamp' phase of Woodroffe et al. (1985c), was associated with rapid sedimentation, and is recorded in the sediments of all large tidal river systems in the region.

In the next phase, aggradation of the plains surface due to wet season deposition of fluviatile sediments would have restricted tidal influence and led to a switch to freshwater ecosystems. As a consequence, from 5300 BP mangroves began to disappear from the plains associated with the tidal flow, becoming increasingly confined to the main channel. Wetlands began to form in low-lying areas of the floodplain cut off from tidal inundation by levee deposits. Certainly by 4000 BP there is evidence for the replacement of mangrove vegetation by freshwater wetlands in some areas at least (Woodroffe et al. 1986, 1987). Elsewhere
on the plains freshwater wetlands did not develop until much later, for example: 1400 BP at Giina, 80 km from the current river mouth (Hope et al. 1985); and 1300 BP on the Magela floodplain (Clark & Guppy 1988).

The river channel at this time was of a slowly migrating, meandering form, and the rate of coastal progradation was high. In the last 2000 years or so coastal progradation has decelerated markedly, with further channel development occurring upstream of the meander segments. Chappell and Woodroffe (1985) term this channel type as 'cuspat e', and suggest that, in maturing systems, due to increased bank-top sedimentation and associated decline in mangroves, undercutting of banks occurs such that wide cuspat e segments form at the expense of sinuous meanders.

There is some evidence that development of cuspat e segments may have been associated with, or contributed to, higher tidal amplitudes of about 1 m in the upper tidal reaches of the South Alligator River (Woodroffe et al. 1986). In historical times erosion of floodplain sediments caused by buffalo may have contributed to reactivation of tidal channel incision and salinisation in some areas (eg Russell-Smith 1985; Finlayson et al. 1988). Currently, the spring tidal range in the Van Diemen Gulf, to the north of Kakadu National Park, is 5–6 m, and extends 105 km upstream on the South Alligator River (Woodroffe 1988).

Contemporary erosion processes

In spite of the intense, highly seasonal rainfall regime, the rate of erosion by world standards is extremely low. Duggan (1989) and Roberts et al. (1992) have estimated rates of denudation for the lowlands of 12 mm and 28 mm per thousand years, respectively. Erosion is so slow because of the generally low slope angles, a widespread surface lag of gravels, protection afforded by leaf litter, and the tendency of the soil to adhere into a weak crust. Significant erosion takes place where the natural surface is disturbed, and is significantly more severe in the early wet season before vegetation cover is well developed, especially on burnt areas.

However, in rehabilitation of cleared areas where coarse gravels are available, and where slopes are reshaped to uniform level surfaces, protective surface lag sheets may be re-established within a wet season (Duggan 1985). Areas not protected by relatively resistant stony surfaces, such as stone-free sandsheets on gentle foot slopes at the base of sandstone hills and scarps, are particularly vulnerable to erosion. Sheet
erosion associated with vehicle tracks in such areas rapidly leads to washouts and gullying in the wet season (Williams 1976). The rate of denudation on the sandstone plateau is even lower, and has been estimated at about 5 mm per thousand years (Roberts et al. 1992).

4.4 Mineral resources

There are a significant number of uranium, precious metal (gold, silver, platinum, palladium) and base metal deposits, mines and prospects in Kakadu. They occur mostly in the south-west. In the main they are of relatively low economic value, except for the uranium deposits, the gold in the Jabiluka prospect, and the Coronation Hill gold, platinum, and palladium deposit. Virtually all of the mineral deposits occur in Early Proterozoic rocks.

Uranium

Total announced reserves of uranium oxide amount to 360,000 tonnes. Uranium mines within the greater boundaries of Kakadu National Park which are either operating or proposed, occur at the Ranger, Jabiluka, and Koongarra lease sites. These leases are excluded from the Park. A fourth site occurs east of the Park, at Nabarlek, in Arnhem Land. Uranium was mined also at 13 small deposits in the South Alligator River valley in the 1950s.

These uranium deposits are all stratabound in schists of the Early Proterozoic Cahill Formation, and were all discovered in the 1970s. The schists were formed by metamorphism of a partly carbonaceous and evaporite sequence of sediments deposited in intertidal to supratidal conditions. The process of mineralisation involved massive alteration of the rocks (mainly addition of magnesium and iron and removal of silica) to form an intensive envelope of chlorite in and around the ore bodies. The age and method of mineralisation is a matter of considerable debate (see for example the many papers in Ferguson & Goleby 1980). However, although some chlorite alteration extends up into the Kombolgie Formation sandstone, there is no significant mineralisation above the unconformity, suggesting that the main alteration and mineralisation events took place before the deposition of the Kombolgie sandstone.
Most of the igneous rocks of the region are enriched in uranium relative to world averages, and some of the granites contain up to 25 ppm or over five times the average concentration. They are considered to be the likely, but not exclusive, uranium source rocks. A probable source of the magnesium in the alteration zones around the ore bodies is the evaporitic rocks which developed in intertidal to supratidal conditions in the lower Cahill Formation. This, and the originally carbonaceous nature of the host rocks, would have assisted precipitation of the metal by adsorption and reduction, and probably explain the tight stratigraphic control on uranium distribution within the Cahill Formation. The absence of evaporites in the western part of Kakadu suggests that there is little likelihood of uranium deposits in that area (Needham 1988).

The uranium deposits of the South Alligator valley, discovered in the 1950s and mined through to the early 1960s, are much smaller and are related to fault zones in which uranium-enriched volcanic rocks are thrown against carbonaceous shales of the Koolpin Formation. Uranium was leached from the volcanics and transported in solution along permeable sandstone interbeds. Upon contact with the carbonaceous shales, the uranium was precipitated through reduction (Needham 1988). Considerable work has been undertaken in recent years, funded by the Commonwealth Government, in rehabilitating these former mine sites in the South Alligator valley, including the burying of radioactive rock dumps.

Both types of uranium deposit in Kakadu are loosely referred to as 'unconformity related type', which implies that they are restricted to sites vertically and horizontally close to the unconformity at the base of the Kambalgie Formation sandstone. However, their distribution in the case of the northern deposits is more closely related to the occurrence of the Cahill Formation in areas of thin soil or sediment cover above the Proterozoic rocks which has facilitated successful exploration using radiometric survey techniques, and in the case of the southern deposits to the juxtaposition of key rock types along fault lines. At Jabiluka, mineralisation has been drilled to a depth of at least 350 m below the unconformity.

Other minerals

East of the South Alligator River the only metal besides uranium to occur in significant quantity is gold. Gold occurs in conjunction with uranium deposits at the Jabiluka deposit and was recovered from
several of the old uranium mines in the South Alligator valley. The Coronation Hill deposit in the upper South Alligator River valley is adjacent to an old uranium-gold mine. Platinum and paladium also occur at Coronation Hill. In the 1930s to 1950s small gold prospects or mines operated at Yemelba (Yimalkba), 8 km south of Mt Partridge, and in the Mundogie Hill area.

Tin was prospected in quartz reefs at Spring Peak in the 1950s, and mined sporadically on a very small scale from gravel deposits from near Myra Falls south of Nabarlek in the 1960s and 1970s. Lead was mined in 1948–1950 from shear zones in altered dolerite at Zamu, 11 km north-east of Coronation Hill. During the 1970s lead and zinc was prospected in quartz-breccia reef zones near Cooinda and east of Mount Partridge range, but no economic deposits were discovered. Exploration for iron in the 1950s near Jim Jim Falls located only thin surface crusts of no economic value.

West of the South Alligator River/Bulademo Tableland there are no uranium or gold deposits, but there are several prospects and small mines of silver-lead-zinc (which commonly occur together) west of Goodparla homestead, and a small copper mine on the Mary River south of the Mary River Ranger Station. All of these occur along north-west trending quartz reefs and breccias. The copper mine was discovered in 1913 and the others in the 1950s and 1960s, with some exploration continuing until the 1980s. In some cases, such as Namoona west of Goodparla homestead, the weathered mineralised zone crops out at the surface as iron-rich gossan, which in places contains galena (lead sulphide). The sandstone ridges north of the Arnhem Highway have detrital pockets of titanium, but exploration during the 1970s failed to find any economically viable deposits.

Unlike the complex genesis of the uranium and uranium-gold deposits, the origin of the base metal deposits of the south-west is relatively simple: they formed from hydrothermal solutions (hot fluids and gases) related to the Early Proterozoic granite intrusions, which squeezed their way along weaknesses in the rock to form mineralised quartz reefs or breccias (zones of broken rock). They form an eastern part of the Cullen Mineral Field, described by Stuart-Smith et al. (1993), in which several large gold deposits have recently been discovered and developed farther west (eg at Pine Creek).
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Flora

Jeremy Russell-Smith

The Alligator Rivers Region, most of which falls in Kakadu National Park, is the most floristically diverse (ie species rich) area of monsoonal northern Australia (Lazarides et al. 1988). The number of known species is still increasing as the result of botanical surveys and taxonomic revisions. Thus, Cowie and Finlayson (1986) recorded 1346 species, Lazarides et al. (1988) recorded 1531 species, and Brennan (1991) recorded 1682 species, including 96 naturalised alien species. This species diversity reflects the diversity of geology, landform and associated plant habitats ranging over extensive lowland lateritic plains, rocky hills, freshwater wetlands, tidal flats, and sandstone scarps and plateaux. The flora associated with sandstone formations of the western Arnhem Land escarpment and plateau is particularly diverse, with many species endemic to the region. Two excellent guides to the flora of the region are available (Brennan 1986; Brock 1988).

The greater part of the Park is savanna of eucalypt-dominated open forest and woodland formations, typically with tall (1–2 m) grassy understoreys. In the seasonal monsoon tropics these open forest and woodland savannas are prone to dry season fires. Fire management issues are discussed in chapter 7. Other important vegetation types
include mangroves, monsoon rainforests, freshwater wetland communities, and heaths.

5.1 Vegetation classification

The vegetation of the Park has been described in a large number of studies, commencing with the landmark regional descriptions of Story (1969, 1973, 1976). These studies were part of work integrating vegetation-soils-geomorphological mapping units termed 'land systems'. More recent studies concern the mapping of vegetation-faunal habitats in the Park (Schodde et al. 1987; scales 1:100 000, 1:250 000), the new vegetation map of the Northern Territory (Wilson et al. 1990; scale 1:1 000 000), and various other studies describing past and present local vegetation patterns, or particular vegetation types (eg mangroves, monsoon rainforests, floodplain communities).

The recent vegetation map of the Northern Territory is used here as a framework for describing the main vegetation types in the Park (Wilson et al. 1990). This map is based on the structure (ie height and degree of canopy closure of major strata), in combination with dominant and/or characteristic species. The structural scheme used by Wilson et al. in their vegetation descriptions is presented here as Table 5.1.

Sixteen broad vegetation types are recognised by Wilson et al. (1990) as occurring in the Park, but not all of these are mapped here given their small extent (Figure 5.1). Classification units described in other studies comparable with, or subsumed within, the broad mapping units of Wilson et al. (1990) are summarised in Table 5.2.

Of note in this table is the diversity of names given to the same or similar vegetation types. This applies particularly to the various eucalypt open-forest and woodland types which lack distinct boundaries (eg Story 1976; Rice & Westoby 1985; Schodde et al. 1987; Bowman et al. 1990). Apart from the dominant eucalypts, woodland communities often are distinguished only by slight differences in species composition.

This problem is compounded when studies are conducted at different scales or use different terminologies. For example, Duff et al. (1991) note that the vegetation in the former Conservation Zone has been mapped
as follows: a large-scale (1:20 000) study recognised 17 vegetation units (Orr et al. 1990); Duff et al.’s own study recognised 12 units (although a regional flora survey for Kakadu National Park Stage Three, vegetation units not mapped as part of survey hence no scale given); another study at 1:50 000, 8 units (Orr et al. 1990); a study at 1:250 000, 4 units (Schodde et al. 1987); and a study at 1:1 000 000, 2 units (Wilson et al. 1990).

Table 5.1 Structural formations and formula used in text for describing main vegetation types

<table>
<thead>
<tr>
<th>Life form &amp; height of strata</th>
<th>100–70%</th>
<th>70–30%</th>
<th>30–10%</th>
<th>1–10%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(4)</td>
<td>(3)</td>
<td>(2)</td>
<td>(1)</td>
</tr>
<tr>
<td>Trees 10–30m</td>
<td>(M) Closed-forest</td>
<td>(L) Low closed-forest</td>
<td>Open-forest</td>
<td>Low open-forest</td>
</tr>
<tr>
<td>Trees 5–10m</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trees &lt;5m</td>
<td>(L) Very low closed-forest</td>
<td>(L) Very low open-forest</td>
<td>Very low wood-forest</td>
<td>Very low open-forest</td>
</tr>
<tr>
<td>Shrubs &gt;2m</td>
<td>(S) Tall closed-shrubland</td>
<td>(S) Tall shrubland</td>
<td>Tall open-shrubland</td>
<td>Tall sparse-shrubland</td>
</tr>
<tr>
<td>Shrubs 1–2m</td>
<td>(Z) Closed shrubland</td>
<td>(Z) Shrubland</td>
<td>Open-shrubland</td>
<td>Sparse shrubland</td>
</tr>
<tr>
<td>Shrubs &lt;2m</td>
<td>(Z) Low closed-shrubland</td>
<td>(Z) Low shrubland</td>
<td>Low open-shrubland</td>
<td>Low sparse-shrubland</td>
</tr>
<tr>
<td>Hummock grasses</td>
<td>(H) Hummock grassland</td>
<td>Hummock grassland</td>
<td>Open-hummock grassland</td>
<td>Sparse-hummock grassland</td>
</tr>
<tr>
<td>Graminoids and grass</td>
<td>(G) Closed grassland</td>
<td>Grassland</td>
<td>Open-grassland</td>
<td>Sparse-grassland</td>
</tr>
<tr>
<td>Sedges</td>
<td>(Y) Closed sedgeland</td>
<td>Sedgeland</td>
<td>Open-sedgeland</td>
<td>Sparse-sedgeland</td>
</tr>
<tr>
<td>Herbs</td>
<td>(F) Closed-herbland</td>
<td>Herbland</td>
<td>Open-herbland</td>
<td>Sparse-herbland</td>
</tr>
</tbody>
</table>

1. A tree is defined as a woody plant usually with a single stem. A shrub is usually a woody plant with many stems arising within 2m of the base.
2. Symbols and numbers given in parenthesis are used to describe the formation by formula, eg Woodland = M2.
3. Foliage cover of <1% is referred to as scattered individuals.

Table 5.2 Vegetation types of Kakadu National Park, following the classification scheme of Wilson et al. (1990) for the Northern Territory (Scale: 1:1 000 000). Other relevant studies are also listed.†

<table>
<thead>
<tr>
<th>Vegetation type (after Wilson et al. 1990)</th>
<th>Other studies in, or relevant to, Kakadu National Park</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Samphire (Scattered chenopod low-shrubland)</td>
<td>Story (1976); Salt marsh (Hegerl et al. 1979; Schodde et al. 1987; Wightman 1988, 1989).</td>
</tr>
<tr>
<td>3 Lowland rainforest (Mixed species closed-forest)</td>
<td>Rainforest, Semi-deciduous forest (Story 1976; Webb &amp; Tracey 1979; Russell-Smith 1984, 1985, 1986, 1991); Monsoon forest (Braithwaite et al. 1984); Lowland monsoon forest (Taylor &amp; Dunlop 1985; Russell-Smith &amp; Dunlop 1987); Coastal, deciduous rainforest (Schodde et al. 1987); Types 8a, b (Duff et al. 1991).</td>
</tr>
<tr>
<td>4 Eucalyptus open-forest (E. miniata–E. tetrodonta open-forest)</td>
<td>Tall, mixed open forest (Story 1976); E. miniata, mixed eucalypt 3, mature mixed types (Burgman &amp; Thompson 1982); Eucalyptus open forest (Taylor &amp; Dunlop 1985); Sub-plateau, open forest (Schodde et al. 1987); Type 5c (Duff et al. 1991).</td>
</tr>
<tr>
<td>5 Eucalyptus miniata woodland</td>
<td>Mid-high open woodland (Lynch &amp; Manning 1988); Baker land system (Wood et al. 1985).</td>
</tr>
<tr>
<td>6 Eucalyptus miniata–E. tetrodonta woodland</td>
<td>Various E. miniata–E. tetrodonta woodlands (Sivertsen &amp; Day 1986); Plateau open-forest (Schodde et al. 1987); Type 5d (Duff et al. 1991).</td>
</tr>
<tr>
<td>7 Eucalyptus tectifica–E. latifolia woodland</td>
<td>Woodland, stunted woodland (Story 1976); Mixed eucalypt types 1, 2 (Burgman &amp; Thompson 1982); Eucalypt woodland (Taylor &amp; Dunlop 1985); Woodland (Schodde et al. 1987); Types 1b, c, e, g, i, 2c, 5b, e, 11a, b (Duff et al. 1991).</td>
</tr>
<tr>
<td>8 Eucalyptus tintinnans low-woodland</td>
<td>Hill woodland (Schodde et al. 1987); E. tintinnans–E. dichromophloia low open woodland (Wilson et al. 1989); Types 1a, h, 5b (Duff et al. 1991).</td>
</tr>
<tr>
<td>9 Melaleuca viridiflora–Eucalyptus low open-woodland</td>
<td>Mixed scrub, savanna (Story 1976); Myrtle–Pandanus savanna, mixed shrubland (Schodde et al. 1987); Types 1e, 6e, 9, 11d, 12, 13 (Duff et al. 1991).</td>
</tr>
<tr>
<td>10 Eucalyptus papuana–E. polycarpa woodland</td>
<td>Pandanus scrub, mixed fringing communities (Story 1976); Upper floodplain fringe (Burgman &amp; Thompson 1982); Margin woodland (Taylor &amp; Dunlop 1985); Myrtle–Pandanus savanna (Schodde et al. 1987); Types 1f, 6a, b (Duff et al. 1991).</td>
</tr>
</tbody>
</table>
Table 5.2 (continued)

<table>
<thead>
<tr>
<th>Vegetation type</th>
<th>Other studies in, or relevant to, Kakadu National Park</th>
</tr>
</thead>
<tbody>
<tr>
<td>(after Wilson et al. 1990)</td>
<td></td>
</tr>
<tr>
<td>11 Paperbark swamp (Melaleuca forest)</td>
<td>Paperbark forest (Story 1976); Forest (Williams 1979); Floodplain fringe (Burgman &amp; Thompson 1982); Melaleuca swamp (Taylor &amp; Dunlop 1985); Melaleuca open forest and woodland (Finlayson et al. 1989); Types 6b, e, 7, 8b (Duff et al. 1991).</td>
</tr>
<tr>
<td>12 Seasonal floodplain (Mixed closed-grassland/sedgeland)</td>
<td>Sedgeland, herbaceous swamp (Story 1976); Annual, perennial swamp etc (Williams 1979); Floodplain macrophytes (Burgman &amp; Thompson 1982; Sanderson et al. 1983); Eleocharis, Oryza swamp, etc (Taylor &amp; Dunlop 1985); Floodplain sedgeland (Schodde et al. 1987); Oryza grassland, Eleocharis sedgeland, etc (Finlayson et al. 1989); Type 12 (Duff et al. 1991).</td>
</tr>
<tr>
<td>13 Escarpment rainforest (Allosyncarpia ternata closed-forest)</td>
<td>Sandstone rainforest, Allosyncarpia forest (Story 1976); Closed forest (Burgman &amp; Thompson 1982; Russell-Smith 1984, 1986, 1991; Sandstone monsoon forest (Taylor &amp; Dunlop 1985; Russell-Smith &amp; Dunlop 1987); Sandstone rainforest, broadleaf shrubbery (Schodde et al. 1987); Monsoon forest, Allosyncarpia forest (Bowman et al. 1990; Russell-Smith et al. 1993); Types 6c, d, 10 (Duff et al. 1991).</td>
</tr>
<tr>
<td>14 <em>E. tetrodonta</em>–<em>E. miniata</em>–<em>E. ferruginea</em> woodland</td>
<td>Sandstone woodland (Story 1976); Sandstone types 1, 2 (Burgman &amp; Thompson 1982); Sandstone eucalyptus woodland (Taylor &amp; Dunlop 1985); Sandstone woodland, open forest (Schodde et al. 1987); Types 1d, 2a, b, 5a, b, c, d, 8e (Duff et al. 1991).</td>
</tr>
<tr>
<td>15 <em>E. phoenicea</em> low woodland</td>
<td><em>E. phoenicea</em> woodland (Sivertsen &amp; Day 1986); Hill woodland, sandstone woodland (Schodde et al. 1987); Types 1d, 5a (Duff et al. 1991).</td>
</tr>
<tr>
<td>16 <em>E. dichromophloia</em>–<em>E. miniata</em> low open-woodland</td>
<td>Sandstone scrub (Story 1976); Sandstone spinifex (Schodde et al. 1987); Shrubby eucalyptus woodland, <em>E. anhemensis</em> woodland, sandstone scrub (Bowman et al. 1990); Types 2b, d, 3, 11c, 15 (Duff et al. 1991).</td>
</tr>
</tbody>
</table>

† Not included are: (i) the early classification units of Story (1969, 1973) as these are covered by Story (1976); (ii) the classification of Kakadu Stage III by Dickinson and Dunlop (1988) since this is updated in Wilson et al. (1990); and the classification of the former Conservation Zone by Orr et al. (1990), since these data are considered also by Duff et al. (1991).
5.2 Vegetation types

The description below considers the main vegetation formations in lowland and escarpment environments. The environmental relations of these vegetation types are summarised in Figure 5.2. Map units refer to Wilson et al. (1990).

Lowland vegetation

Mangroves (Mangal low closed-forest), map unit 105: Mangroves grow along the muddy tidal reaches of all major coastal river systems in the Park. Wells (1985) describes the mangroves of the coastal river systems as among the most diverse (i.e. species rich) in northern Australia. Of 24 woody mangrove species used in his analysis of 82 northern Australian river systems, Wells records at least fourteen from any one Kakadu river system.

Taking a broader definition of mangrove species composition, Wightman (1988) lists 39 of 47 Northern Territory species as occurring in Kakadu. These include three woody species of restricted occurrence in the Northern Territory: Rhizophora lamarckii, Sonneratia lanceolata (syn. S. caseolaris), and possibly a new species of Sonneratia known only from the Wildman River estuary. As well, a rare mangrove vine, Finlaysonia obovata, has recently been recorded from the South Alligator River.

Descriptions of Kakadu mangrove vegetation are provided by Hegerl et al. (1979) and Davie (1985). These tidal forests are dominated principally by the genera Bruguiera, Ceriops, Rhizophora (all Rhizophoraceae), Avicennia (Verbenaceae), and Sonneratia (Sonneratiaceae). In a detailed study of mangrove vegetation on the South Alligator River, Davie (1985) estimated a current extent of 29 km², of which 20 km² occurs within 25 km of the mouth. This is twenty-eight times less than the 800 km² of mangrove vegetation for the existing South Alligator River floodplain around 6000 years ago, when the sea level stabilised at its present level (Woodroffe et al. 1985). The greatest development of present-day mangrove vegetation in the Park is associated with the estuary of the West Alligator River (Hegerl et al. 1979).

Although classic zonation patterns are observed in Kakadu mangrove forests, particularly in gently sloping lower estuarine and coastal
situations, considerable variability exists. For example, Davie (1985) described the distribution of Kakadu mangroves with reference to four habitat categories of tidal inundation, the occurrences of which in any one locality are determined primarily by river morphology and hydrodynamic processes. For details of mangrove patterning in Kakadu National Park the interested reader is referred to Hegerl et al. (1979) and Davie (1985).

**Samphire (Scattered chenopod low-shrubland), map unit 106:** Samphire occurs as sparse, low shrubby vegetation, on tidal, typically fine clay, salt flats. On gently sloping prograding shorelines samphire may occupy extensive exposed areas between taller mangrove vegetation under frequent tidal influence, and the landward fringe. It comprises mostly hardy succulent shrubs: *Halosarcia indica*, *Suaeda arbusculoides*, *Tecticornia australasica* (all Chenopodiaceae), and *Sesuvium portulacastrum* (Aizoaceae). As well, grasses (*Cynodon dactylon*, *Sporobolus virginicus*) and various sedges (*Cyperus*, *Fimbristylis*) are often present.

**Lowland rainforest (Mixed species closed-forest), map unit 1** (Note: With the exception of Barron Island this vegetation type is not mapped in Figure 5.1 given its small extent in the Park): Lowland rainforests occur as small habitat islands in a vast sea of eucalyptus or paperbark (Melaleuca) dominated vegetation. In the Kakadu region they occupy two distinct habitats. Rainforests associated with perennial water occur at springs and seepages. Such rainforest patches are typically small, ranging from 1–5 ha. Canopies are dominated by evergreen trees, particularly various *Syzygium* species (*S. angophoroides*, *S. minutuliflorum*, *S. nervosum*), and the tall *Carpentaria* feather palm (*Carpentaria acuminata*) which is endemic to the Northern Territory.

Most lowland rainforest in the Park, however, occurs on well drained soils which dry out in the dry season. Such habitats include coastal beach dunes, the upland margins of riverine floodplains, seasonal watercourses, and rock outcrops.

These forests are also mostly small, from 1–100 ha; larger patches are associated mostly with floodplain margins of the East Alligator River, and coastal situations, especially Barron Island. Canopies comprise many deciduous species, and range in height from over 20 m on more favourable sites, to a tangled mass of vines and shrubs often no more than 3 m in height on seasonally harsh sites such as rock outcrops.
Figure 5.1 Vegetation classification of Kakadu National Park, after Wilson et al (1990)

Legend

1. Lowland rainforest (Mixed species closed forest)
2. Allobarbaria ternata closed forest
3. Eucalyptus tetrodonta, E. miniata, E. ferruginea woodland
4. Eucalyptus open forest (E. miniata, E. tetrodonta open forest)
5. Eucalyptus tectifica, E. latifolia woodland
6. Eucalyptus tintinnans low woodland
7. Melaleuca viridiflora, Eucalyptus low open woodland
8. Mixed closed grassland/sedgeland (seasonal floodplain)
9. Eucalyptus tetrodonta, E. miniata, E. bleeseri woodland
10. E. tetrodonta, E. miniata, E. dichromophloia woodland
11. Eucalyptus miniata woodland
12. Eucalyptus miniata, E. tetrodonta woodland
13. E. tetrodonta, E. miniata, E. dichromophloia woodland
14. E. miniata, E. tetrodonta woodland
15. Eucalyptus tectifica, E. latifolia woodland
Typical tree species include black wattle (*Acacia auriculiformis*), milkwood (*Alstonia actinophylla*), kapok (*Bombax ceiba*), *Canarium australianum*, *Drypetes lasiogyna*, banyan (*Ficus vires*), beach hibiscus (*Hibiscus tiliaceus*), *Maranthes corymbosa* and *Sterculia quadrifida*.

These forests, together with rainforest vegetation of the sandstone escarpment described below, are the vestiges of rainforests which occurred more widely across Australia as recently as 15 million years ago (Truswell 1990). Fossil pollen from sediment cores collected near the source of the South Alligator River indicate that rainforest, similar to modern-day Antarctic beech (*Nothofagus*) forest, occurred in the region possibly as much as 50 million years ago (Truswell 1982). The demise of these forests is attributed to the onset of marked rainfall seasonality, and associated factors such as increased burning, and competition from other species better adapted to these conditions (eg eucalypts and grasses).

Many modern day rainforests, however, occur on geologically recent landforms, such as beach dunes, indicating that constituent species are readily dispersed, probably by birds (especially fruit pigeons) and fruit bats (*Pteropus* spp.); over 70% of Northern Territory rainforest species possess small fleshy fruits amenable to such dispersal (Russell-Smith & Dunlop 1987).

**Eucalyptus open-forest** (*E. miniata*-*E. tetrodonta* open-forest), **map unit 4**: Eucalyptus open-forest comprises mixed stands of tall eucalypts (16 m or more), especially Darwin woollybutt (*E. miniata*) and stringybark (*E. tetrodonta*), over a ground layer dominated by tall grasses (eg *Heteropogon triticeus*, *Sorghum* spp.). The grass layer may attain heights of as much as 3 m in the wet season; providing substantial fuel for fires later in the dry season.

This is the second most common vegetation type, after the *Eucalyptus tectifica*-*E. latifolia* woodland community described below. It is widespread across northern coastal regions of the Northern Territory (Wilson et al. 1990). The vegetation type is associated with lateritic peneplains in undulating terrain where soils are typically deep, well drained, and light textured (eg sandy loams). In the north of the Park this vegetation occurs over deeply weathered metamorphic rocks and granite, and in the south on flat terrain over sand and laterite-covered
Mesozoic siltstone and sandstone. On rises and upper slopes where soils are shallower and more gravelly, rusty-barked bloodwood (*Eucalyptus bleeseri*) is often a major component. Other common woody species include ironwood (*Erythrophleum chlorostachys*), various *Acacia* species, *Buchanania obovata*, turkey bush (*Calytrix extipulata*), *Xanthostemon paradoxus*, and the lowland fan palm, *Livistona humilis*.

**Eucalyptus miniata woodland, map unit 11:** This vegetation type occurs mostly between Darwin and Pine Creek on steep rocky hills with frequent rock outcrops and shallow gravelly soils. The vegetation is very rare in Kakadu and occurs in one small isolated area on the south-western boundary of the Park (Figure 5.1). The overstorey is dominated by *E. miniata*, commonly occurring with minor *E. clavigera*, *E. tectifa*, and *Erythrophleum chlorostachys*. The ground layer typically is mixed tussock grassland, with *Heteropogon triticeus*, *Sehima nervosum* and *Chrysopogon fallax* the predominant species.

**Eucalyptus miniata—E. tetrodonta woodland over curly spinifex (*Plectrachne pungens*) grassland, map unit 12:** Occupying small areas in the extreme south of the Park, this unit is similar to unit 4 in several respects but the presence of curly spinifex in the understorey reflects poorer sandy soils and lower soil moisture availability conditions. The vegetation is developed in areas with a thin Mesozoic siltstone cover over the Kombolgie sandstone along the eastern side of the Bulodemo Tableland (also known as the Marrawal Plateau).

In addition to *E. miniata* and *E. tetrodonta*, other upper storey species include *E. bleeseri*, *E. phoenicea*, and ironwood (*Erythrophleum chlorostachys*). The sparse shrubby mid-layer contains an open woodland assemblage of *Eucalyptus* and *Acacia* species, with patches of fan palm (*Livistona humilis*) and *Lophostemon lactifluus*. In addition to the curly spinifex, the ground layer includes *Sorghum intrans* and other hummock grasses.

**Eucalyptus tectifera—E. latifolia woodland, map unit 15:** *E. tectifera—E. latifolia* woodland is the most widespread vegetation in northern coastal regions of the Northern Territory. It is more stunted than eucalyptus open-forest, being dominated by scattered low trees to 12 m tall, over a sparse shrub-layer and tall grasses, notably *Sorghum* spp., *Heteropogon triticeus* and *Chrysopogon fallax*.
Figure 5.2 Vegetation profile for the northern, central and southern sections of Kakadu National Park, using the vegetation classification units of Wilson et al. (1990)

(A) NORTHERN

(B) CENTRAL
Though the canopy is usually dominated by northern box (*E. tectifica*) and, to a lesser extent, round-leaf bloodwood (*E. latifolia*), a variety of other species are common components, especially *Erythrophleum chlorostachys*, *Brachychiton diversifolius*, *Terminalia ferdinandiana*, *Petalostigma pubescens*, *Eucalyptus confertiflora*, *E. grandiflora*, and other eucalypts. In their quadrat-based study of different vegetation types in the Park, Taylor and Dunlop (1985) note that woodland communities have the most species per unit area (0.16 ha quadrats). They recorded as many as 82 species in woodland quadrats.

In contrast to eucalyptus open-forest, these woodlands occur on gentle slopes in the undulating lowlands over metamorphic rocks, granite and dolerite, and, in the Coronation Hill–Katherine River area, over felsic volcanic rocks. Soils tend to be heavier textured loams and clay loams, shallower, and less well drained. In hilly terrain rock exposure is common, often following long strike ridges, with poor skeletal soils on the slopes. This woodland type extends over most of the landscape except on very poorly drained soils associated with colluvial plains.

**Eucalyptus tintinnans** low-woodland, map unit 21: This woodland vegetation occurs in the southern sector of the Park associated with rugged rocky hills and strike ridges of felsic volcanics, quartzite, granite and minor sedimentary rocks, where the soils are shallow, coarse-grained, and gravelly. The overstorey comprises scattered low trees of principally salmon gum (*Eucalyptus tintinnans*), *E. dichromophloia*, *E. tectifica* and *Erythrophleum chlorostachys*, over a tall grass layer of *Sorghum* spp. and *Heteropogon triticeus*. Other major woody species include *Cochlospermum fraseri*, *Gardenia megasperma*, *Grevillea decurrens*, *Livistona humilis*, *Petalostigma quadriloculare*, *Terminalia ferdinandiana*, and *Xanthostemon paradoxus*.

**Melaleuca viridiflora–Eucalyptus low open-woodland**, map unit 51: This map unit comprises structurally similar, if floristically dissimilar, vegetation types comprising low, scattered trees over dense grassy understoreys which tend to occur in poorly drained colluvial and alluvial situations, commonly on the black soil plains in the middle reaches of rivers between the sandy channel and floodplain stages.

The main vegetation type of this map unit is open-woodland dominated by *Melaleuca viridiflora* in association with various eucalypts such as
E. polycarpa and E. latifolia, Buchanania obovata, Grevillea pteridifolia, Livistona humilis, Melaleuca nervosa, Pandanus spiralis and the grasses Chrysopogon fallax, Sorghum spp. and Themeda avenacea. This vegetation type is widely distributed on poorly drained, fine textured soils fringing watercourses and in depressions. Schodde et al. (1987) note that this vegetation type also often forms an ecotone (ie boundary) between woodland and the dry-land margin of paperbark swamp.

In damp sandy situations similar communities are dominated by Banksia dentata and Grevillea pteridifolia, with scattered emergent tree species such as Eucalyptus polycarpa, E. ptychocarpa, Lophostemon lactifluus, Melaleuca viridiflora, M. nervosa and Pandanus spiralis. The grass layer is dominated typically by fine blade Eriachne species (E. triseta, E. burkittii, E. avenacea).

Eucalyptus papuana–E. polycarpa woodland, map unit 18 (Note: this vegetation type not mapped in Figure 5.1 given its small extent): This woodland community is mostly associated with the margins of alluvial plains or the silty levees of larger river systems. Soils are generally poorly drained, clayey, and subject to inundation for short periods during the wet season. It is often located between woodland and paperbark swamp.

The tree layer is dominated by ghost gum (Eucalyptus papuana) associated with a wide range of species, notably: swamp bloodwood (E. polycarpa), Erythrophleum chlorostachys, Melaleuca viridiflora, Pandanus spiralis, Planchonia careya; and the grasses, Chrysopogon fallax, Heteropogon triticeus, and Sorghum spp.

Paperbark swamp (Melaleuca forest), map unit 53: Extensive paperbark swamps occur on the seasonally inundated floodplains of all large river systems in the Park. This vegetation type is dominated by one or more tall Melaleuca species: M. cajuputi, M. leucaandra, M. nervosa, and M. viridiflora. Williams (1979) notes that the latter two species occur in swamps which are inundated for relatively short periods. The former two species (M. cajuputi, M. leucaandra) will occur in areas subject to waterlogging for prolonged periods of up to eight months. These two species have adventitious roots which may develop into substantial trunks.
Finlayson et al. (1989) detailed the floristic composition of these forests on the Magela–East Alligator River floodplain. They note that paperbark swamps merge with open floodplain vegetation, and that both the canopy cover and understorey composition is very variable; the understorey typically comprises species from adjacent open floodplain vegetation.

Melaleuca forests also fringe large rivers throughout Kakadu. In these situations the above Melaleuca species, and also M. argentea, often occur with other riparian species.

Seasonal floodplain (Mixed closed-grassland/sedgeland), map unit 54: The vegetation of seasonally inundated floodplains forms a complex mosaic in response to often subtle topographic changes, and temporal patterns of water depth and periodicity. Thus, in a detailed study of the Magela–East Alligator River floodplain, Finlayson et al. (1989, 27) noted that, as a consequence of the above factors:

The floodplain species are constantly responding to changing physical and biological conditions. As a result the composition of the plant communities changes more or less continuously during the wet-dry cycle. Similarly, at any one point of time, plant communities change spatially along environmental gradients such as water depth. Therefore, when describing vegetation pattern on seasonally flooded wetlands, a plant community must be defined temporally as well as spatially.

Given such variability it is understandable that many of the studies of Kakadu seasonal floodplain vegetation outlined in Table 5.1 describe a number of classification units; the study of Finlayson et al. (1989), for example, described eight vegetation types, as well as two melaleuca-dominated units.

The dynamism of seasonal floodplain communities is a reflection also of the recent evolution of the riverine floodplains. As discussed in the previous chapter, recent studies have demonstrated that Kakadu’s freshwater wetlands have only developed over the past few thousand years or so, attributable to sediment infilling of riverine valleys following the last post-glacial rise in sea level, and its stabilisation approximately 6000 years ago (Chappell & Grindrod 1985; Hope et al. 1985; Woodroffe et al. 1985; Clark & Guppy 1988).
PLATE 5.1 Mangroves fringing Pt Farewell. In the top left background, deciduous vine thicket vegetation occurs on shallow dunes (Jeremy Russell-Smith).

PLATE 5.2 Northern lowland areas of the Park are clothed in tall open-forest dominated by stringybark (Eucalyptus tetrodonta) and woollybutt (E. muirata) often with an understorey of sand palms (Livistona spp.). Soils are typically infertile deep red sandy loams (Jeremy Russell-Smith).
PLATE 5.3 Eucalyptus-dominated woodlands cover extensive areas of the Park. The ground cover typically comprises tall annual grasses (e.g. Sorghum spp.) which may grow to as much as 3m in the wet season; when cured, such grasses provide the major fuel for dry season fires (Diane Lucas).

PLATE 5.4 Floodplain vegetation is typically a complex of tall paperbark (Melaleuca spp.) communities (background), open herbaceous communities, and open water billabongs (Diane Lucas).
PLATE 5.5 The lotus lily (Nelumbo nucifera) is once again becoming widespread on Kakadu's floodplains after removal of Asian water buffalo (Diane Lucas).

PLATE 5.6 The major rainforest type of the escarpment and plateau is dominated by one hardy species of tree, Allosyncarpia ternata, a species restricted to the western Arnhem Land region. Allosyncarpia-rainforest occurs in a range of situations, from moist valley-bottoms to rugged rocky slopes (Jeremy Russell-Smith).
PLATE 5.7 Small patches of escarpment rainforest are restricted to perennial streams in protected sandstone gorges (Carolyn Johns/Wildlight Photo Agency).

PLATE 5.8 Rocky areas of the plateau are mantled by a rich diversity of scattered hardy shrubs and spinifex grasses (Jeremy Russell-Smith).
PLATE 5.9 Hildegardia australiensis, the deciduous green-trunked tree in the photo, occurs in small isolated populations in a few areas in the Park. The species, only recently described, is illustrative of the botanical richness of the Arnhem Land plateau region (Jeremy Russell-Smith).

PLATE 5.10 Mimosa pigra, the scourge of Top End floodplains, is now effectively under control in Kakadu National Park thanks to the efforts of a dedicated team over the past decade. Here adult mimosa plants are being sprayed. This area will require revisiting for many years in order to treat emerging seedlings (Garry Lindner).
Jeremy Russell-Smith

Open floodplain vegetation ranges from open-water communities associated with permanent waterbodies such as billabongs, to transient, ephemeral communities of herbs, grasses, and sedges associated with seasonally inundated, cracking clay soils which dry out completely in the dry season.

Water-lilies (Nymphaoides indica, Nymphaea spp.) and the Indian lotus lily (Nelumbo nucifera) are associated with perennial waters. Such conditions also favour the development of floating mats of species not rooted to the substrate (e.g. the grasses Hymenachne acutigluma, Leersia hexandra). Such rafts are often sufficiently stable to walk on, and are favoured crocodile nesting habitat.

In seasonally wet situations a variety of communities may develop: grasslands dominated by an annual species of rice (Oryza rufipogon; syn. O. meridionalis); grasslands dominated by perennials (Hymenachne acutigluma, Pseudoraphis spinescens); sedgelands dominated by spike-rushes (Eleocharis spp.); and herbfields which colonise exposed substrates as waters recede.

For descriptions of Kakadu seasonal floodplain communities the interested reader is referred to Williams (1979), Taylor and Dunlop (1985) and, especially, Finlayson et al. (1989).

Escarpment vegetation

Escarpment rainforest (Allosyncarpia ternata closed-forest), map unit 2: As with lowland rainforest the escarpment forests occur both at perennially moist sites such as springs, and more widely on a range of seasonally dry, often rugged, freely draining sandstone landforms. In both situations, however, escarpment rainforests are dominated typically by one large species of evergreen tree, Allosyncarpia ternata. As the sole canopy species in most, but especially harsh, seasonally dry, situations, it provides a protective canopy for all other species, both plant and animal. It is also relatively fire-tolerant. Aboriginal people call this tree anbinik.

These allosyncarpia escarpment rainforests are perhaps the most remarkable rainforests in the Northern Territory, and conform to a rainforest type that occurs nowhere else in northern Australia (Russell-Smith et al. 1993). Allosyncarpia itself is restricted to the actively
eroding northern and western rims of the Arnhem Land escarpment. Its nearest relatives occur in isolated populations in northern Queensland, New Guinea and New Caledonia, strongly suggesting Gondwanic origins (Johnson & Briggs 1984). Unlike many other Northern Territory rainforest species, Allosyncarpia is poorly dispersed, possessing relatively large dry seeds which fall 2–3 metres at most beyond parental canopies.

In protected, moist sandstone gorges, canopies may be as tall as 40 m. As well as Allosyncarpia, other common tree species in such situations include Calophyllum sil, Gmelina schlechteri, Horsfieldia australianum, Ilex arnhemensis, Melaleuca leucadendra, Syzygium angophoroides, S. minutuliflorum, Xanthostemon eucalyptoides and the Carpentaria palm, Carpentaria acuminata.

In seasonally dry situations canopy height may be as low as 10 m, with a relatively open, fire-ravaged understorey. Other hardy species associated with Allosyncarpia include small trees such as Cryptocarya exfoliata, Glycosmis sapindoides, Rhodamina australis, Xanthostemon psidioide, X. umbrosus and the vines Desmos wardianus, Gynochodes australiensis and Melodorum affinis; in the Northern Territory all these species are either restricted to, or are most common in, allosyncarpia forest.

**Eucalyptus tetrodonta**–**E. miniata**–**E. ferruginea** woodland, map unit 8: This vegetation type is widespread through western Arnhem Land. It is of limited extent in Kakadu, occurring mostly in the south (Figure 5.1) on sandy soils over sedimentary rocks which typically form a less rugged landscape than that of the Arnhem Land plateau in Kakadu. The vegetation is mostly woodland where it is associated with shallow, gravelly sands; where sands are deeper, it occurs also as open-forest.

The vegetation is dominated by *E. tetrodonta* in association with *E. miniata*, *E. ferruginea* and a variety of other eucalypts. Other prominent species include Callitris intratropica (cypress pine), Erythrophleum chlorostachys, Petalostigma quadriloculare, Xanthostemon paradoxis, and the tall grasses, Heteropogon triticeus and Sorghum plumosum.

**Eucalyptus phoenicea** low woodland, map unit 29: This vegetation type, though widespread in a discontinuous band across the Northern Territory between 13° and 16°S on generally prominent rocky ranges, is
limited to a small area of interbedded sandstone and basalt lava supporting patchy skeletal soils in the extreme south of Kakadu.

Scarlet gum (*E. phoenicea*) dominates the overstorey, which also includes minor *E. ferruginea*, *E. dichromophloia* and *E. miniata*. A mixed species sparse-shrub layer is usually present and comprises species such as *Erythrophleum chlorostachys*, *Calytrix extipulata*, *Petalostigma quadriloculare*, *Distichostemon hispidulus* and *Terminalia canescens*. The understorey of hummock grassland is dominated by curly spinifex (*Plectrachne pungens*), and includes a range of other grasses, notably *Eriachne obtusa*.

**Eucalyptus dichromophloia—E. miniata** low open-woodland, map unit 32: This vegetation type describes a complex of low, shrubby communities with scattered emergent trees (eg *E. dichromophloia*, *E. arnhemensis*, *E. miniata*, *E. herbertiana*, *E. phoenicea*, *E. ferruginea*, *E. kombolgiensis*, *Erythrophleum chlorostachys*), often over a substantial cover of spinifex grasses (eg *Plectrachne pungens*, *Triodia microstachya*). In many situations the vegetation is a low sandstone heath comprising a diversity of shrubs and herbaceous species, including the following genera: *Acacia* (Mimosaceae); *Hibbertia* (Dilleniaceae); *Phyllanthus* (Euphorbiaceae); *Cajanun*, *Jacksonia*, *Tephronia* (Fabaceae); *Goodenia* (Goodeniaceae); *Utricularia* (Lentibulariaceae); *Mitracrum* (Loganiaceae); *Hibiscus* (Malvaceae); *Calytrix* (Myrtaceae); *Eriachne*, *Micriara* (Poaceae); *Grevillea* (Proteaceae); *Styliadium* (Stylidiaceae); *Pityrodia* (Verbenaceae).

This is the principal vegetation cover of the rugged, mostly bare rock, sandstone terrain of the Arnhem Land plateau and escarpment. Soils, where present, are skeletal stony or gravelly sands.

### 5.3 Significant vegetation types

The best known ecosystems conserved in the Park are the extensive wetland floodplains, and riverine ecosystems; the heaths, woodlands, and rainforest communities of the western Arnhem Land sandstone escarpment; and the vast expanse of continuous lowland eucalypt forest and woodland.

In assessing the World Heritage status of the Park on floristic evidence, Bowman and Wilson (1987) noted that, although the Park does not contain any unique formation, it conserves outstanding examples of the most important ecosystems in northern Australia. They also noted that
the tracts of eucalypt forest represented in Kakadu form part of the last large expanse of eucalypt forest in Australia.

Of particular note are Kakadu’s monsoon rainforest patches, with six of 16 Northern Territory floristic assemblages represented in the Park (Russell-Smith 1991). Duff et al. (1991) note the restricted occurrence of heath vegetation on fine textured sediments associated with the margins of Marrawal Plateau, in the south of the Park. Such heaths are probably very rare in northern Australia.

5.4 Rare and threatened species

Based on published lists of rare and threatened vascular plant species occurring in the Park (as included in Briggs & Leigh 1988), ‘notable species’ (Duff et al. 1991), and current listings of rare Northern Territory species on the data base of the Northern Territory Herbarium (CCNT), some 58 species occurring in Kakadu are considered rare (see Table 5.2, although this is a provisional list).

Various rare taxa listed by Briggs and Leigh (1988) have been omitted in the light of more recent collections; omitted species are listed at the end of Table 5.3. The status of some species listed here is likely to change with further botanical work, especially in Arnhem Land. Various undescribed taxa are not included because of incomplete knowledge of their taxonomic affinities. Using similar data to that presented here, Leach (1987, 1988) has discussed the significance of rare or threatened plants in some areas of the Park.

Eighteen species included in Table 5.3 are recorded only from the Park. These include five recently recorded new species of Acacia, Calytrix, Grevillea, Heliotropium, and possibly a new genus in the family Simaroubaceae (Duff et al. 1991). The majority of above listed rare taxa, including nearly all rare taxa restricted to the Park, occur in open woodlands and heaths associated with sandstone habitats. Among those species known only from the Park are the following:

- *Arthrochilus bynesii* is a small ground orchid known only from one location, in the south of the Park. Because it has not been observed since 1970, Briggs and Leigh (1988) list it as one of only four endangered species in the Northern Territory.
Table 5.3 Rare or threatened plant species known to occur in Kakadu National Park

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1 Taxonomic nomenclature follows Dunlop (1990)

2 Where given, symbols and abbreviations follow data as given in Briggs and Leigh (1988), where: 1=known from Type collection only; 2=geographic range <100 km; 3=geographic range 100+ km; E=endangered; V=vulnerable; R=rare (not threatened); K=poorly known; C=population reserved; A=adequately reserved; I=inadequately reserved

Rare species recorded in Briggs and Leigh (1988) but omitted here are: Asteromyrtus arnhemica (3RC; syn. Melaleuca arnhemica); Boronia affinis (3RC); Calytrix micrarioides (2RC); Croton aff. byrnesei (3RC); Eriachne bleeseri (3RC); Fimbristylis clavata (3K); Fimbristylis pilifera (3KC); Gonocarpus implexus (3RC); Grevillea polycadica (3RC); Micraira subspicata (2RC) Operculina brownii (3K); Plagiocarpus axillaris (3K).
Three other orchids from collections made in Kakadu are listed as rare. These are *Dendrobium lobii*, *Malaxis latifolia* and *Nervilia aragoana*. Each of these species is known only from isolated populations; *M. latifolia* in the Northern Territory is known from a single location.

- *Calytrix* spp. (Fam. Myrtaceae) are generally small hardy shrubs with showy flowers and aromatic foliage. Three rare *Calytrix* heath species are so far known only from the Park, where they occur in geographically small populations in sandstone escarpment habitats. The radiation of calytrix in the western Arnhem Land escarpment exemplifies the diversity of sandstone heath species in the region.

- *Eucalyptus koolpinensis* is a box known only from populations near Koolpin Creek and upper Gimbatts Creek.

- *Hildegardia australiensis* is a tall deciduous tree (Fam. Sterculiaceae) known from 12 sites in the Park, each comprising but a small population of adults. Professor AJ Kostermans of the Herbarium Bogoriense, Indonesia, suggests that this species may be *H. sundaica*, known from a single tree, at Sumbawa, eastern Indonesia.

- *Micraira* spp. are low, mat forming grasses which occur in shallow depressions typically devoid of soil, on sandstone pavements. Generally spiky to touch, these remarkably hardy, so-called resurrection grasses may completely dehydrate in the absence of moisture and yet spring back to life within 24 hours after rain. *Micraira* species have radiated extensively in sandstone formations of the western Arnhem Land escarpment and Kimberley region of north-western Australia.

In Arnhem Land a number of *Micraira* species are each known from only one or two sites, reinforcing patterns of microhabitat specialisation as seen in other plant groups occurring in this habitat (eg *Calytrix, Pityrodia*).

- *Neobynesia suberosa* (Fam. Rutaceae) is a small woody plant which clings to rock crevices in the north-western Arnhem Land escarpment. The specialised habitat and restricted geographic range of this and many other sandstone escarpment species reflect microhabitat specialisation.

- *Pityrodia* spp. (Fam. Verbenaceae) are small, attractive and highly aromatic shrubs found throughout the sandstone open woodlands
and heaths. As with *Calytrix*, a number of species exhibit highly localised and/or patchy distributions.

- *Sonneratia* sp. is a mangrove tree (Fam. Sonneratiaceae) with close affinities to *S. lanceolata*. It is known only from a population in the Wildman River estuary in Stage One of the Park (Wightman 1987).

### 5.5 Weeds

As used here, the term ‘weed’ refers to introduced plants which are not native to the Kakadu region, and which are established, and which propagate in the wild. In a survey of weeds in the Park, Cowie and Werner (1987, 1993) found that 89 of 1526 (5.8%) recorded species are weeds. In the most recent checklist available for the Park, Brennan (1991) lists 96 weeds out of a total of 1682 (5.7%) species for the Alligator Rivers Region. The proportion of weeds in the regional flora is similar to that for the whole Northern Territory (Bowman et al. 1988), but less than the 10% recorded for Australia as a whole (Michael 1981).

Weeds are more prevalent at sites disturbed by humans, such as settlements and roads, than elsewhere. Thus Cowie and Werner (1993) found in a survey of weed habitats that 59 weed species were associated with disturbed sites compared with 37 in natural habitats. Sandstone habitats were the least infested. Severe weed infestations have been reported also in habitats disturbed by feral ungulates, particularly buffalo (Braithwaite et al. 1984; Russell-Smith 1984).

The number of weed species in the Park has increased at the rate of 1.6 species per year since 1948, and is expected to continue increasing (Cowie & Werner 1987). Of the 89 weed species recorded by Cowie and Werner (1993), 20 are grasses. Other well represented families are the Fabaceae (15 spp.), Malvaceae (seven), Caesalpinaceae (five), Asteraceae (five), and Amaranthaceae (four). The most common, widespread weeds in the Park are shrubs or herbs, *Hypis suaveolens*, *Sida acuta*, *S. cordifolia*, *Alysicarpus vaginalis*, *Euphorbia hirta* and the perennial vine, *Passiflora foetida*.

Those species which pose the most significant threat to natural habitats in Kakadu, however, are: *Mimosa pigra*, a spiny, aggressively invasive shrub, especially of seasonal floodplains; *Salvinia molesta*, a water fern; *Brachiaria mutica*, a perennial floodplain grass; and *Pennisetum polystachion*, a vigorous perennial grass capable of invading a range of dry-land...
habitats. Other aggressive weeds identified by Cowie and Werner (1987) include the as yet rare legume trees and shrubs Cassia alata, C. fistula and Leucaena leucocephala.

A ranked list of weeds in the Park as classified by Cowie and Werner (1987) is given in Table 5.4. It is noted that some weeds listed as Priority 2 have the potential to become major weeds. For example, the currently restricted Andropogon gayanus, a vigorous dry-land perennial grass which, like Pennisetum polystachion mentioned above, has the potential to increase the intensity of fires on sites where it is established.

**Major weeds**

Detailed accounts of major weed species in Kakadu National Park are given in Cowie and Werner (1987, 1993) and Cowie et al. (1988). Discussion is limited here to the four main weed species identified by Cowie and Werner (1987, 1993) as likely to have the greatest impact, for the present at least, on natural habitats in the Park.

i) *Mimosa pigra*: A spiny shrub capable of blanketing seasonal floodplains within a few years of establishment, populations of mimosa are expanding rapidly across a 450 km arc in the north-west of the Northern Territory (Lonsdale et al. 1989).

Competition by *Mimosa pigra* may completely exclude some native plants and animals (Braithwaite et al. 1989; Morton et al. 1989). Conversely, a formerly rare marsupial mouse, Smynthopsis virginiae, may have benefited from the spread of mimosa (Braithwaite & Lonsdale 1987).

The salient features of the biology of *Mimosa pigra* under Australian conditions are as follows (Lonsdale et al. 1989). Seed production can begin in the first year under ideal conditions, with as many as 9000 seeds per square metre. Seeds can remain viable for 23 years under field conditions. Seed pods are readily dispersed by floodwaters. Germination can occur under a relatively dense canopy, although survival over the dry season is typically poor. When established, plants up to 3 m in height can form impenetrable thickets at densities of 1 to 3 plants per square metre. All other species may be excluded. Populations can at least double their infestation area each year.
Mimosa pigra, a native of central America, is now widespread in the tropics. It was introduced to the Northern Territory apparently late last century, but populations have only begun to explode in the past 30 to 40 years (Lonsdale et al. 1989). Its presence in the Park was first detected in 1981; by 1987, 49 separate infestations had been recorded (Skeat et al. 1987). It is currently known from 150 separate infestations (ANCA file records, 1993).

All known infestations of mimosa in the Park are considered to be under control in that infestations comprise only seedbanks and emerging seedlings (Skeat et al. 1987; ANCA file records, 1993). This has been achieved by a dedicated mimosa eradication program at an annual cost of approximately $300 000 on 1993 figures. Old infestations are monitored, and new sites identified by rigorous searches of the floodplains.

Although several biological control organisms are being tried these have had little impact on mimosa populations (Lonsdale et al. 1989). To date, as well as spraying, seedbanks are burnt and the sites fenced to limit spread by animals, especially buffalo (Skeat et al. 1987).

Despite the success of the mimosa control program in Kakadu, populations are continuing to increase on floodplains both to the east and west of Kakadu which makes control within the Park difficult. Increasing numbers of mimosa infestations are being reported from the East Alligator River floodplain, the seed sources for which are extensive infestations on the Arnhem Land side of the river. Control of mimosa on the Arnhem Land side is now being achieved through a major chemical control program using the herbicide tebuthiuron, and by ground-based search and destroy crews.

ii) Salvinia molesta: Salvinia is an aquatic, free-floating fern, native to Brazil which propagates vegetatively, and can double in population size in as little as 2.2 days (see Plate 8.7). The formation of dense floating mats late in the dry season lowers oxygen concentrations, light levels and pH, and substantially raises sub-surface water temperatures (Cowie & Werner 1987).

First located in the Park on the Magela Creek system in 1983, it was anticipated that the release in 1984 of a biological control agent, the
Table 5.4 Major weed species in Kakadu National Park as ranked by Cowie and Werner (1987)*

**Priorities:**
(Only weeds in the first four categories are listed here.)

1. Major weeds in small to large infestations: eliminate where practicable and prevent spread.
2. Moderate to minor weeds in small infestations (some potentially major weeds): eliminate where practicable and prevent spread.
3. Moderate weeds, medium to large infestations: prevent spread and reduce populations where practicable.
4. Moderate weeds, medium infestations: prevent spread and reduce populations where practicable.

<table>
<thead>
<tr>
<th>Species</th>
<th>Priority</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acanthospermum hispidum</td>
<td>2</td>
<td>star burr</td>
</tr>
<tr>
<td>Alteranthera sp.</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Alteranthera pungens</td>
<td>2</td>
<td>khaki weed</td>
</tr>
<tr>
<td>Amaranthus viridus</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Anacardium occidentale</td>
<td>2</td>
<td>cashew</td>
</tr>
<tr>
<td>Andropogon gayensis</td>
<td>2</td>
<td>gamba grass</td>
</tr>
<tr>
<td>Axonopus compressus</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Bauhinia alba</td>
<td>2</td>
<td>bauhinia</td>
</tr>
<tr>
<td>Bothriochloa pertusa</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Brachiaria mutica</td>
<td>1</td>
<td>para grass</td>
</tr>
<tr>
<td>Caesalpinia pulcherrima</td>
<td>2</td>
<td>pride of Barbados</td>
</tr>
<tr>
<td>Calopogonium mucunoides</td>
<td>2</td>
<td>calopo</td>
</tr>
<tr>
<td>Calotropis procera</td>
<td>2</td>
<td>caltrop</td>
</tr>
<tr>
<td>Cassia fistula</td>
<td>2</td>
<td>golden shower</td>
</tr>
<tr>
<td>Cenchrus echinatus</td>
<td>4</td>
<td>Mossman River grass</td>
</tr>
<tr>
<td>Centrosema braziliannuim</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Chloris barbata</td>
<td>3*</td>
<td>purple-top chloris</td>
</tr>
<tr>
<td>Crotalaria goreensis</td>
<td>2</td>
<td>Gambia pea</td>
</tr>
<tr>
<td>Cryptostegia madagascariensis</td>
<td>2</td>
<td>Madagascan rubber vine</td>
</tr>
<tr>
<td>Delonix regia</td>
<td>2</td>
<td>poinciana</td>
</tr>
<tr>
<td>Desmodium tortuosum</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Euphorbia heterophylla</td>
<td>2</td>
<td>annual poinsettia</td>
</tr>
<tr>
<td>Gmelina arborea</td>
<td>2</td>
<td>gmelina</td>
</tr>
<tr>
<td>Gossypium hirsutum</td>
<td>4</td>
<td>cotton</td>
</tr>
<tr>
<td>Hibiscus sabdariffa</td>
<td>4</td>
<td>rosella</td>
</tr>
<tr>
<td>Hyptis suaveolens</td>
<td>3*</td>
<td>hyptis, horehound</td>
</tr>
<tr>
<td>Ipomoea quamoclit</td>
<td>2</td>
<td>Cupid’s flower</td>
</tr>
<tr>
<td>Ipomoea triloba</td>
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<td></td>
</tr>
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Table 5.4 (continued)

<table>
<thead>
<tr>
<th>Species</th>
<th>Priority</th>
<th>Common Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jatropha spp.</td>
<td>2</td>
<td>jatropha, physic nuts</td>
</tr>
<tr>
<td>Lantana camara</td>
<td>2</td>
<td>lantana</td>
</tr>
<tr>
<td>Leucaena leucocephala</td>
<td>1</td>
<td>coffee bush</td>
</tr>
<tr>
<td>Macroptilium lathyroides</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Malachra fasciata</td>
<td>3*</td>
<td></td>
</tr>
<tr>
<td>Merremia dissecta</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Mimosa pigra</td>
<td>1</td>
<td>giant sensitive plant</td>
</tr>
<tr>
<td>Mimosa pudica</td>
<td>2</td>
<td>common sensitive plant</td>
</tr>
<tr>
<td>Passiflora foetida</td>
<td>3*</td>
<td>stinking passion vine</td>
</tr>
<tr>
<td>Pennisetum pedicellatum</td>
<td>3*</td>
<td></td>
</tr>
<tr>
<td>Pennisetum polysachion</td>
<td>1</td>
<td>mission grass</td>
</tr>
<tr>
<td>Ruellia tuberosa</td>
<td>2</td>
<td>popping seed</td>
</tr>
<tr>
<td>Salvinia molesta</td>
<td>1</td>
<td>salvinia</td>
</tr>
<tr>
<td>Senna alata</td>
<td>1</td>
<td>candle bush</td>
</tr>
<tr>
<td>Senna obtusifolia</td>
<td>3*</td>
<td>sickle pod</td>
</tr>
<tr>
<td>Senna occidentalis</td>
<td>4*</td>
<td>sickle pod</td>
</tr>
<tr>
<td>Sesamum indicum</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Sida acuta</td>
<td>3*</td>
<td>spiny-head sida</td>
</tr>
<tr>
<td>Sida cordifolia</td>
<td>3*</td>
<td>flannel weed</td>
</tr>
<tr>
<td>Solanum nigrum</td>
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<td></td>
</tr>
<tr>
<td>Sorghum alburnum</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Stachytrapheta spp.</td>
<td>2</td>
<td>snake weed</td>
</tr>
<tr>
<td>Stylosanthes hamata</td>
<td>3*</td>
<td>stylo</td>
</tr>
<tr>
<td>Themeda quadrivalvis</td>
<td>2</td>
<td>grader grass</td>
</tr>
<tr>
<td>Tribulus spp.</td>
<td>2</td>
<td>caltrop</td>
</tr>
<tr>
<td>Urochloa mosambicensis</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Xanthium occidentale</td>
<td>2</td>
<td>Nogoora burr</td>
</tr>
</tbody>
</table>

* common or successful weed species in the Park, after Cowie and Werner (1987)

Weevil *Cyrtobagous salviniae*, would be as effective in the Park as it had proven in other parts of eastern Australia. By 1987, however, thick mats of salvinia had developed on some Magela billabongs, and a preliminary study by Skeat (1990) suggested that lethally high water temperatures late in the dry season might be contributing to lack of development in weevil populations.

Subsequent work by researchers from the CSIRO Division of Entomology has demonstrated that, at least in those years where
billabongs have been flushed by preceding wet season floodwaters, *Cyrtobagous* does in fact exert significant control (Julien & Storrs 1993, 1994). The model proposed by Julien and Storrs is as follows. At the height of the wet season, weeds and weevils are largely dispersed by floodwaters. With cessation of the wet season salvinia grows rapidly to form mats, with neither nutrients nor temperatures limiting to growth of the weed. The weevil, however, takes considerably longer to build up to population sizes sufficient to effectively control salvinia; this occurs typically later in the dry season. Under increasing weevil population pressure the salvinia mats are damaged and finally sink, and open water conditions are resumed (see Plate 8.8). So successful is the weevil in eating out its host food plant later in the dry season that its populations consequently crash. This typical boom and bust cycle, while not conducive for effecting year-round high-level control of salvinia, does point to the very significant impact which the weevil has on the weed.

Unfortunately, however, the weevil does not work so effectively in shallow swampy situations where some ground-moisture is maintained throughout the year. In such situations the weevil cannot sink the salvinia and the weed persists throughout the dry season. As well, the weevil does not work well in situations where salvinia mats are tied up with grasses and sedges, such as occurs typically on billabong margins.

At present, salvinia is widespread on the Magela Creek and East Alligator River systems, and in recent years has been found on Nourlangie Creek, a tributary of the South Alligator River. Current practice involves the spreading of weevils into all new infestations, strict quarantine, and strategic spraying of certain waterbodies (eg. where roads cross infested creeks) using a kerosene-based mix, AF100, which sinks floating mats of salvinia.

iii) *Brachiaria mutica* (para grass): Para grass was introduced to the East Alligator River floodplain, near Oenpelli, earlier this century as a fodder grass. A predominantly vegetatively reproducing perennial, it is invading floodplain habitats on the Magela Creek and East Alligator River systems especially. This expansion seems to have been facilitated by removal of grazing pressure from water buffalo (Cowie et al. 1988). It is often a major component of floating mats, and is possibly also invading important waterfowl feeding habitats. It has the potential to
invade substantial areas of floodplain habitat, from billabongs to the upland margins, replacing native species. Its wide usage in the pastoral industry as fodder rules out biological control. It is of major concern to the Park as it occurs in two large infestations on the South Alligator River, at Munmarlary. It is very difficult to eradicate, with preliminary trials indicating that it is susceptible to chemical applications of glyphosate only at certain active periods in the growth cycle (ANCA file records).

iv) *Pennisetum polystachion* (mission grass): This hardy perennial is an aggressive coloniser of disturbed areas. It is spreading quickly in the Top End, and its late curing and large stature may provide increased fuel for late dry season fires. These comments apply also to gamba grass (*Andropogon gayanus*), an aggressive coloniser of roadsides, floodplain margins, and other disturbed sites. At the present time both these species, while present in the Park, are of relatively restricted occurrence and both are subject to successful ongoing control and monitoring programs.

**Dispersal of weeds**

Seeds are dispersed following ingestion by birds and fruit bats, adhesion to a variety of animal species, by wind, and flood waters, and by vehicles (Skeat et al. 1987; ANPWS 1991). Lonsdale and Lane (1990) found that up to 70% of vehicles in the Park carried seeds, many being weed species. Of particular concern is the potential for inadvertant spread of mimosa, salvinia, and the above grass species, on vehicles (and boats), given their widespread occurrence in other parts of the Top End.

**Cultivated species**

As well as weeds, Cowie and Werner (1987) reported that 300 or so exotic species were being cultivated in the Park. Most of these were in Jabiru (256 species) and East Jabiru (91), but large numbers were present also at settlements such as Nourlangie Camp (35), Mudginberri (24), and the East Alligator Ranger Station (22). Cowie and Werner (1987) noted that many of these cultivated exotics could become weeds, and that thirteen were already established. A follow-up consultancy, undertaken by Brock and Cowie in 1992, indicated that the situation of weeds at settlements in the Park was substantially the same as that reported by Cowie and Werner in 1987. Subsequently, work has continued on the
removal of potentially highly invasive species, especially some of the legumes (eg *Leucaena leucocephala*, *Senna* spp.).

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6

Fauna

Tony Press, John Brock and Alan Andersen

In the eucalypt woodlands and forests of Kakadu, moving through the floodplains, hidden in the monsoon rainforests, in the gorges and gullies of the sandstone and lurking in the rivers, streams and billabongs, is a unique assemblage of animals, among the most diverse in Australia. Over one-third of Australia's bird species can be found in Kakadu, more than 50 different fish, over 120 reptiles and amphibians, over 60 species of mammals, over 100 species of termites and 300 species of ants plus tens of thousands of other invertebrates. Some species are found nowhere else in the world, while for others Kakadu provides an important refuge or stronghold.

The geographic diversity of Kakadu, the conjunction of the sandstone Arnhem Land plateau with the rivers, lowland forests, the floodplains and the coast creates a rich diversity of habitats across a wide climatic gradient; these factors all interact to produce the rich array of fauna in Kakadu.

There is a distinct north-south gradient in both the bird and mammal fauna which coincides with the rapid reduction in rainfall with distance from the coast. Assemblages of vertebrates are related to different habitat with associations being most strongly expressed in the bird and reptile species (Woinarski & Braithwaite 1993). Some groups like the

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reptiles have distinct species associations with the sandstone country while the mammals and birds of the lowland woodlands are generally widely distributed across the landscape. Some habitats are depauperate in some groups and rich in others: the monsoon forests have a paucity of mammals, reptiles and frogs (Menkhorst & Woinarski 1992; Gambold & Woinarski 1993), though they provide key habitat for the frugivorous avifauna of the region.

Though there is a comprehensive inventory of the vertebrates of Kakadu, the invertebrates are not well described or extensively studied. The Environmental Research Institute of the Supervising Scientist (ERISS) has undertaken a great deal of work in aquatic ecology and taxonomy and various divisions of the CSIRO have also researched invertebrates in the Park.

The terrestrial vertebrate fauna of Kakadu has been studied in two major surveys since 1980 (Braithwaite 1985; Woinarski & Braithwaite 1991). These surveys concentrated on Kakadu, however, their regional context has been assessed by Woinarski (1992a). These studies have highlighted the importance of the nature conservation values of Kakadu National Park and given impetus to the nature conservation effort in northern Australia.

6.1 Fauna habitats

Within the monsoonal tropics of north-western Australia, the distribution of animals and plants shows little overriding east-west variation, but a strong north-south trend related to the rainfall gradient. The intertwining of localised edaphic factors, geomorphology, vegetation association and species distributions combine to produce a pattern of vegetation to which we can relate species distribution and abundance.

The habitat classifications used by Schodde and Martensz (1973) and Schodde et al. (1987) are based on vegetation units over the major geomorphic regions within Kakadu. We have generally followed these in this chapter, but have at times renamed some of these classifications. These are easily referred to vegetation associations in chapter 5.

Escarpment and plateau

The sandstone formations of the western Arnhem Land escarpment, plateau and outliers vary from sheer cliffs and extended scree slopes to
large flat plains. The plateau areas are covered largely with a eucalypt woodland growing on shallow sand, intergrading with spinifex grasslands and heath shrubland on exposed rock platforms and boulder slopes. Rainforests of the region, which are dominated by the evergreen tree allosyncarpia (Allosyncarpia ternata), typically line the floors and lower slopes of protected gorges, and occur on both perennially wet and seasonally dry sites (Russell Smith et al. 1993). This vast rocky catchment gives rise to numerous streams, which drain the system through a network of joints and intersecting gorges.

These sandstone habitats support a distinctive assemblage of animals, some of which are relict or restricted range species. The escarpment habitats are dry season refuges for freshwater fish, including several species with restricted distributions.

Notable species among the sandstone assemblage are the jewelled velvet gecko (Oedura gemmata), Pamela’s gecko (Gehyra pamela), giant cave gecko (Pseudothecadactylus lindneri), the skinks Ctenotus coggeri and Egernia arnhemensis, Oenpelli python (Morelia oenpelliensis), chestnut-quilled rock-pigeon (Petrophassa rufipennis), white-throated grass wren (Amytornis woodwardi), black wallaroo (Macropus bernardus), nabarlek (Petrogale concinna), large rock-rat (Zyzomys maini) and sandstone antechinus (Pseudanatechinus bilarni). Caves and crevices dotted along the escarpment provide homes for such significant bats as the orange horseshoe bat (Rhinoniceris aurantius) and ghost bat (Macroderma gigas), while also providing refuge for the carpenter frog (Megistolotis lignarius), Copland’s rock frog (Litoria coplandi) and Litoria personata. Leichhardt’s grasshopper (Petasida ephippigera) is associated with sandstone heath shrubs.

**Open forest and woodland**

The vegetation of the dry lowland areas of the Park is dominated by tropical eucalypt communities, and though these often comprise a complex of intergrading woody, shrubby and grass species, two prominent formations stand out.

The taller open forests, to about 16 m high, are dominated by the Darwin stringybark (Eucalyptus tetrodonta) and Darwin woollybutt (E. miniata), with a variety of understorey trees such as ironwood (Erythrophleum chlorostachys), green plum (Buchanania obovata), other eucalypts, the common
sand palm (*Livistona humilis*), and a ground layer dominated by tall grasses such as spear grass (*Sorghum* spp.) and *Heteropogon*.

The more widespread formation comprises lowland woodlands characterised by a more open, lower canopy (to about 12m) and generally stunted and more scattered trees with a sparse shrub layer and ground cover of tall grasses. *Eucalyptus tectifica* and *E. latifolia* are usually dominant, though many other eucalypts, ironwood, billygoat plum (*Terminalia ferdinandiana*) and quinine tree (*Petalostigma pubescens*) are common. They occur on undulating gentle slopes, with slightly heavier and less well-drained soils than those of the open forests.

These open forest and woodland habitats support a great diversity of birds, many of which are widespread and highly mobile. Common birds include lorikeets, parrots and cockatoos, numerous honeyeaters, friarbirds, butcherbirds, finches, and raptors such as falcons, kites and hawks. A notable species of these habitats is the partridge pigeon (*Geophaps smithii*).

Mammals include the agile wallaby (*Macropus agilis*), antilopine wallaroo (*M. antilopinus*), nocturnal mammals such as northern brown bandicoot (*Isoodon macrourus*), northern quoll (*Dasyurus hallucatus*), brushtail possum (*Trichosurus vulpecula*) and sugar glider (*Petaurus breviceps*). Common reptiles include frilledneck lizard (*Chlamydosaurus kingii*), sand goanna (*Varanus gouldii*) and two-lined dragon (*Diporiphora bilineata*). Skinks of many species abound in the woodlands.

**Southern stony hills**

The habitat is characterised by rounded hills and ranges with an extensive cover of pebbles and small stones supporting eucalypt woodland to about 10 m tall. These locations are rich in birds, mammals and reptiles. Examples are the Gouldian finch (*Erythrura gouldiae*), hooded parrot (*Psephotus dissimilis*), Calaby's mouse (*Pseudomys calabyi*), Kakadu dunnart (*Sminthopsis bindi*), short-tailed mouse (*Leggadina forresti*), common planigale (*Planigale maculata*) and the skink *Ctenotus spaldingi* (Schodde et al. 1987; Woinarski 1992b).

**Rivers and riparian woodland**

Tall mixed woodland and paperbarks fringing the larger rivers are habitats for the rare red goshawk (*Erythrotriorchis radiatus*) and rufous
owl (*Ninox rufa*). These corridors form dispersal routes for species such as the pied-imperial pigeon (*Ducula bicolor*), shining flycatcher (*Myiagra alecto*), cicadabird (*Coracina lenuirostris*), spangled drongo (*Dicrurus hottentottus*), the large-footed mouse-eared bat (*Myotis adversus*), northern blossom-bat (*Macroglossus minimus*), black and little red flying-foxes (*Pteropus spp.*), the rodent, grassland melomys (*Melomys burtoni*), the skink *Carlia rufilatus*, and several snakes including the common tree snake (*Dendrelaphis punctulata*). The freshwater streams support numerous fishes and invertebrates and the upper reaches are of particular importance for the pig-nosed turtle (*Carettochelys insculpta*).

**Floodplains and paperbark swamps**

The floodplains, woody margins and surrounding paperbark swamps are of particular importance for waterfowl. In the late dry season, spectacular aggregations of magpie geese (*Anseranas semipalmata*), ducks and other waterfowl can be found in and around the receding waterholes on the drying floodplains. Two birds, the yellow chat (*Epthianura crocea*) and grass owl (*Tyto capensis*), are found only on these sites in the Park. Both freshwater and estuarine crocodiles occur, as well as numerous freshwater fish, turtles, cherabin crayfish (*Macrobrachium* sp.) and crabs, water-snakes such as the Arafura file snake (*Acrochordus arafurae*) and many species of frogs.

**Mangroves and estuarine habitats**

The mangrove and estuarine regions support such species as the striated heron (*Butorides striatus*), eastern reef egret (*Egretta sacra*), chestnut rail (*Eulabeornis castaneoventris*), mangrove robin (*Eopsaltria pulverulenta*), mangrove golden whistler (*Pachycephala melanura*) and brahminy kite (*Haliastur indus*). Barramundi (*Lates calcarifer*) move downstream from billabongs and the upper reaches of streams in the wet season to breed. Other species include estuarine crocodiles (*Crocodylus porosus*), freshwater and ocean fish, mud-crabs and other crustaceans, many shellfish, several snakes including sea-snakes, and the mangrove monitor (*Varanus indicus*).

**Foreshore and beaches**

Beaches, dunes, and swales characterise this 100 km stretch of the Park’s coastline. Numerous coastal birds, particularly migratory species, occur
along these stretches, and include beach stone-curlew (*Esacus neglectus*), plovers, terns, sandpipers, pied and sooty oystercatchers (*Haematopus* spp.), eastern curlew (*Numenius madagascariensis*) and whimbrel (*N. phaeopus*). Sea turtles – the green sea turtle (*Chelonia mydas*), flatback sea turtle (*Natator depressus*, formerly known as *Chelonia depressa*) and Pacific or olive ridley sea turtle (*Lepidochelys olivacea*) – are recorded as nesting on the beaches of Field Island and West Alligator Head area (Miles 1988; Guinea 1990). Dugong (*Dugong dugon*) also occur.

**Monsoon rainforests**

Both wet and seasonally dry rainforests occur in each of the sandstone, lowland and coastal regions. They are found generally as small, isolated patches scattered throughout these environments, though the allosyncarpia forests in sandstone gorges, and rainforest on floodplain margins, may form more extensive tracts. Wet rainforests are associated with springs and seepages, while the drier rainforests occur on seasonally dry sites such as scree slopes, rock outcrops, riparian and floodplain fringes, and coastal dunes. Pools, moisture, dense shade and lower temperature are typical of the tall spring jungles, where trees may grow to 20–30 m. In contrast, rainforest vegetation on harsh exposed sites forms a tangled thicket of vines and predominantly deciduous shrubs and trees 3 to 5 m in height.

Rainforests are used by species from other habitats, especially open forest and woodland, during the dry season. They are also used by birds which migrate between patches or from distant regions. Some foods, particularly fleshy fruits, are seasonally abundant in rainforests. Birds such as orange-footed scrubfowl (*Megapodius reinwardt*), rainbow pitta (*Pitta iris*), banded fruit-dove (*Ptilinopus cinctus*), rose-crowned fruit-dove (*Ptilinopus regina*) and pied-imperial pigeon (Torres Strait pigeon) are associated with monsoon rainforest habitats.

A number of snakes, particularly the carpet python (*Morelia spilota*), common tree snake and brown tree snake (*Boigia irregularis*) are found in these forests, as are several frogs, especially *Sphenophryne adelphoe* which is found in sandstone sites. Coastal rainforests contain rookeries of nankeen night herons (*Nycticorax caledonicus*) (Braithwaite & Estbergs 1982). Many insects, including moths and butterflies, tend to congregate inside jungle patches (Kikkawa & Monteith 1980).
Evergreen sandstone rainforests have been identified as important sites for certain insect groups, in particular breeding populations of aquatic insects (Wells 1990).

Woinarski (1993) suggests that rainforests may be important to birds such as the Pacific baza or crested hawk (*Aviceda subcristata*), grey goshawk (*Accipiter novaehollandiae*), large-tailed nightjar (*Caprimulgus macrurus*), little kingfisher (*Alcedo pusilla*) and white-browed robin (*Poecilodryas superciliosa*).

### 6.2 Mammals

The Park's native mammals include 64 known species, rich by both regional and national standards, comprising slightly over one-quarter of all of Australia's terrestrial mammals. The mammal species comprise: one monotreme (egg laying mammal), the echidna; eight dasyurids (carnivorous marsupials); one bandicoot; three possums; seven macropods (kangaroos and wallabies); twenty-eight bats; fourteen rodents (rats and mice); one dog, the dingo; and the sea mammal, the dugong. Occasionally dolphins are seen in the tidal reaches of the large rivers but their identification is uncertain. A check list of mammals is given in Table 6.1.

Of these mammals the recently described Kakadu dunnart (Van Dyck et al. 1994), nabarlek (a small rock wallaby), orange horseshoe bat, ghost bat, and lesser wart-nosed horseshoe bat (*Hipposideros stenotis*) are all regarded as vulnerable or potentially so (Burton & Pearson 1987; Churchill, in press; Churchill & Helman 1990; Kennedy 1990; Woinarski & Braithwaite 1991). Other mammals such as the diadem horseshoe bat (*Hipposideros diadema*), white-striped sheathtail-bat (*Taphozous kapalgensis*, known only from the Kapalga area of Kakadu), black wallaroo, sandstone antechinus and rock ringtail possum (*Pseudocheirus dahlia*, restricted to sandstone habitats) are regionally restricted species. The status of a recently described rodent, Calaby's mouse, is uncertain (Woinarski & Braithwaite 1991).

Among the Dasyurids, nocturnal carnivores include the sandstone antechinus, brush-tailed phascogale (*Phascogale tapoalafa*), red-cheeked dunnart (*Sminthopsis virginiæ*) and Kakadu dunnart (Van Dyck et al. 1994).
### Table 6.1 Checklist of native mammals in Kakadu National Park*

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Monotremes</strong></td>
<td></td>
</tr>
<tr>
<td><em>Tachyglossus aculeatus</em></td>
<td>echidna</td>
</tr>
<tr>
<td><strong>Dasyurids</strong></td>
<td></td>
</tr>
<tr>
<td><em>Antechinus bellus</em></td>
<td>fawn antechinus</td>
</tr>
<tr>
<td><em>Dasyurus hallucatus</em></td>
<td>northern quoll</td>
</tr>
<tr>
<td><em>Phascogale tapoatafa</em></td>
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<tr>
<td><em>Planigale ingrami</em></td>
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<tr>
<td><em>Planigale maculata</em></td>
<td>common planigale</td>
</tr>
<tr>
<td><em>Pseudantechinus bilarni</em></td>
<td>sandstone antechinus</td>
</tr>
<tr>
<td><em>Sminthopsis virginiae</em></td>
<td>red-cheeked dunnart</td>
</tr>
<tr>
<td><em>Sminthopsis bindi</em></td>
<td>Kakadu dunnart</td>
</tr>
<tr>
<td><strong>Bandicoots</strong></td>
<td></td>
</tr>
<tr>
<td><em>Isoodon macrourus</em></td>
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</tr>
<tr>
<td><strong>Possums</strong></td>
<td></td>
</tr>
<tr>
<td><em>Petaurus breviceps</em></td>
<td>sugar glider</td>
</tr>
<tr>
<td><em>Pseudocheirus dahlii</em></td>
<td>rock ringtail possum</td>
</tr>
<tr>
<td><em>Trichosurus vulpecula</em></td>
<td>brushtail possum</td>
</tr>
<tr>
<td><strong>Macropods</strong></td>
<td></td>
</tr>
<tr>
<td><em>Macropus agilis</em></td>
<td>agile wallaby</td>
</tr>
<tr>
<td><em>Macropus antilopinus</em></td>
<td>antilopeine wallaroo</td>
</tr>
<tr>
<td><em>Macropus bernardus</em></td>
<td>black wallaroo</td>
</tr>
<tr>
<td><em>Macropus robustus</em></td>
<td>common wallaroo (euro)</td>
</tr>
<tr>
<td><em>Onychogalea unguifera</em></td>
<td>northern nail-tail wallaby</td>
</tr>
<tr>
<td><em>Petrogale brachyotis</em></td>
<td>short-eared rock wallaby</td>
</tr>
<tr>
<td><em>Petrogale concinna</em></td>
<td>nabarlek</td>
</tr>
<tr>
<td><strong>Bats and Flying-foxes</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Family Pteropodidae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Macroglossus minimus</em></td>
<td>northern blossom-bat</td>
</tr>
<tr>
<td><em>Pteropus alecto</em></td>
<td>black flying-fox</td>
</tr>
<tr>
<td><em>Pteropus scapulatus</em></td>
<td>little red flying-fox</td>
</tr>
<tr>
<td><strong>Family Megadermatidae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Macroderma gigas</em></td>
<td>ghost bat</td>
</tr>
<tr>
<td><strong>Family Hipposideridae</strong></td>
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</tr>
<tr>
<td><em>Hipposideros ater</em></td>
<td>dusky horseshoe-bat</td>
</tr>
<tr>
<td><em>Hipposideros diadema</em></td>
<td>diadem horseshoe-bat</td>
</tr>
<tr>
<td><em>Hipposideros stenotis</em></td>
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<tr>
<td></td>
<td>orange horseshoe-bat</td>
</tr>
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<td><strong>Family Emballonuridae</strong></td>
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</tr>
<tr>
<td><em>Saccolaimus flaviventris</em></td>
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</tr>
<tr>
<td><em>Saccolaimus saccoloaimus</em></td>
<td>naked-rumped sheathtail-bat</td>
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<tr>
<td><em>Taphozous georgianus</em></td>
<td>common sheathtail-bat</td>
</tr>
<tr>
<td><em>Taphozous kapalgensis</em></td>
<td>white-striped sheathtail-bat</td>
</tr>
</tbody>
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*Note: The table includes some species that may not have common names in English.*

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<table>
<thead>
<tr>
<th>Family Molossidae</th>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Chaerophon jobensis</em></td>
<td>northern mastiff-bat</td>
</tr>
<tr>
<td></td>
<td><em>Mormopterus beccarii</em></td>
<td>Beccari's mastiff-bat</td>
</tr>
<tr>
<td></td>
<td><em>Mormopterus loriae</em></td>
<td>little northern mastiff-bat</td>
</tr>
<tr>
<td>Family Vespertilionidae</td>
<td><em>Chalinolobus gouldii</em></td>
<td>Gould's wattled bat</td>
</tr>
<tr>
<td></td>
<td><em>Chalinolobus nigrogriseus</em></td>
<td>hoary bat</td>
</tr>
<tr>
<td></td>
<td><em>Eptesicus caurinus</em></td>
<td>northern brown bat</td>
</tr>
<tr>
<td></td>
<td><em>Eptesicus finlaysoni</em></td>
<td>little cave bat</td>
</tr>
<tr>
<td></td>
<td><em>Miniopterus schreibersii</em></td>
<td>common bent-wing bat</td>
</tr>
<tr>
<td></td>
<td><em>Myotis adversus</em></td>
<td>large-footed mouse-eared bat</td>
</tr>
<tr>
<td></td>
<td><em>Nyctophilus arnhemensis</em></td>
<td>Arnhem Land long-eared bat</td>
</tr>
<tr>
<td></td>
<td><em>Nyctophilus bitax</em></td>
<td>North Queensland long-eared bat</td>
</tr>
<tr>
<td></td>
<td><em>Nyctophilus geoffroyi</em></td>
<td>lesser long-eared bat</td>
</tr>
<tr>
<td></td>
<td><em>Nyctophilus walker</em></td>
<td>pygmy long-eared bat</td>
</tr>
<tr>
<td></td>
<td><em>Pipistrellus westralis</em></td>
<td>western pipistrelle</td>
</tr>
<tr>
<td></td>
<td><em>Scotorepens balstoni</em></td>
<td>western broad-nosed bat</td>
</tr>
<tr>
<td></td>
<td><em>Scotorepens greyi</em></td>
<td>little broad-nosed bat</td>
</tr>
<tr>
<td>Rodents</td>
<td><em>Conilurus penicillatus</em></td>
<td>brush-tailed rabbit-rat</td>
</tr>
<tr>
<td></td>
<td><em>Hydromys chrysogaster</em></td>
<td>water rat</td>
</tr>
<tr>
<td></td>
<td><em>Leggadina forresti</em></td>
<td>short-tailed mouse</td>
</tr>
<tr>
<td></td>
<td><em>Melomys burtoni</em></td>
<td>grassland melomys</td>
</tr>
<tr>
<td></td>
<td><em>Mesembrinomys gouldii</em></td>
<td>black-footed tree-rat</td>
</tr>
<tr>
<td></td>
<td><em>Mesembrinomys macrurus</em></td>
<td>golden-backed tree-rat</td>
</tr>
<tr>
<td></td>
<td><em>Pseudomys delicatulus</em></td>
<td>delicate mouse</td>
</tr>
<tr>
<td></td>
<td><em>Pseudomys nanus</em></td>
<td>western chestnut mouse</td>
</tr>
<tr>
<td></td>
<td><em>Pseudomys calabyi</em></td>
<td>Calaby's mouse</td>
</tr>
<tr>
<td></td>
<td><em>Rattus colletti</em></td>
<td>dusky rat</td>
</tr>
<tr>
<td></td>
<td><em>Rattus tunneyi</em></td>
<td>pale field rat</td>
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<tr>
<td></td>
<td><em>Xeromys myoides</em></td>
<td>false water-rat</td>
</tr>
<tr>
<td></td>
<td><em>Zyzomys argurus</em></td>
<td>common rock-rat</td>
</tr>
<tr>
<td></td>
<td><em>Zyzomys maini</em></td>
<td>large rock-rat</td>
</tr>
<tr>
<td>Canines</td>
<td><em>Canis familiaris dingo</em></td>
<td>dingo</td>
</tr>
<tr>
<td>Marine mammals</td>
<td><em>Dugong dugon</em></td>
<td>dugong</td>
</tr>
</tbody>
</table>

The fawn antechinus (*Antechinus bellus*) is one of the most common small mammals in open forest habitats. Also common is the northern quoll, found mainly in open forest and woodland, where it occupies hollow logs and tree limbs by day. It is often seen in camping areas at night.

Common and widespread in the woodlands and open forests, the northern brown bandicoot feeds on insects and seeds on the ground. It may also scavenge at night in camping grounds.

Of the three possums, the rock ringtail possum occurs mainly in rocky areas and the brushtail possum and diminutive sugar glider are widespread throughout woodlands.

The most commonly seen macropod is the agile wallaby, associated with rainforest margins (both sandstone and lowland) and grasslands, while the larger, relatively social antilopine wallaroo, grazes in open forest and woodland. The black wallaroo is endemic to the sandstone regions and is locally quite common (Press 1988, 1989).

The echidna is generally associated with moist sandstone areas, particularly rocky piles and boulder heaps. It feeds mainly on ants and termites.

Bats are the largest group of the Park's mammals represented by 28 species. The widespread little red flying-fox (*Pteropus scapulatus*) and black flying-fox (*Pteropus alecto*) roost in riverine rainforest or paperbark trees by day, often in large, noisy colonies, feeding by night on fruit and nectar in various habitats. They are important pollinators of many eucalypts and paperbarks, and disperse certain monsoon forest fruits, especially figs. Another nectar-feeder is the restricted northern blossom-bat, a very small flying-fox considered rare by Burton and Pearson (1987) but often observed locally in Kakadu. Most of the other bats are insectivorous, though the ghost bat also eats small vertebrates, and the large-footed mouse-eared bat eats fish.

Fourteen species of rodents are known from the Park, a high number for the region. This varied group encompasses tree, ground and water-dwelling species, seed-eaters and fruit-eaters ranging in size from the rabbit-sized black-footed tree rat (*Mesembriomys gouldii*) to small mice such as the rare Calaby's mouse. Species found in rocky sandstone sites include the common rock-rat, *Zyzomys argurus*; in lowland open forest
and woodland, the delicate mouse, *Pseudomys delicatulus*; in riparian rainforest, the grassland melomys; and in the floodplains, the dusky rat, *Rattus tunneyi*. The otter-like water-rat (*Hydromys chrysogaster*) is found near billabongs and some tidal creeks, while the rare false water-rat (*Xeromys myoides*) has been recorded from near the South Alligator River and at two other Top End locations. The golden-backed tree-rat (*Mesembriomys macrurus*) is known locally from Deaf Adder Creek, although there has been a recent unconfirmed siting of this species near the South Alligator River in the southern part of Kakadu. It also occurs in the Kimberley region of Western Australia.

The mobile and widespread dingo (*Canis familiaris dingo*) is the most recently arrived native animal in Kakadu. It is thought to have reached Australia in the company of humans around 5000–6000 years ago. It can often be seen at night or early in the morning walking along roads in the Park.

The dugong occurs in the coastal region of the Park where it feeds on sea grasses in the shallow waters.

Eight species of introduced wild and feral domestic mammals occur in the Park. They are the water buffalo (*Bubalis bubalis*), cattle (*Bos taurus*), horse (*Equus caballus*), donkey (*E. asinus*), pig (*Sus scrofa*), cat (*Felis catus*), black rat (*Rattus rattus*) and house mouse (*Mus domesticus*).

### 6.3 Birds

The Park contains 289 bird species, about one-third of Australia’s bird fauna (see Appendix IV). Several notable species breed within the Park, many are rare locally or throughout their range, and several are regarded as threatened or vulnerable. Numerous migratory birds arrive seasonally, particularly in the wetlands, from other regions of Australia and overseas. The southern part of the Park around the South Alligator River valley and to the south provides an important refuge area for two spectacular but rare species, the Gouldian finch and the hooded parrot (Brouwer & Garnett 1990).

**Sandstone regions**

These habitats contain a distinctive group of birds, characterised by the sandstone shrike-thrush (*Colluricincla woodwardi*), chestnut-quilled rock-
pigeon (*Petrophassa rufipennis*), variegated fairy-wren (*Malurus lamberti*) and white-lined honeyeater (*Meliphaga albineata*) from open woodland areas, and great bowerbird (*Chlamydera nuchalis*), banded fruit-dove, barking owl (*Ninox connivens*) and helmeted friarbird (*Philemon buceroides*) from sandstone rainforest.

The sparsely-vegetated spinifex plateaux are the favoured habitat of the white-throated grass-wren, whose known range includes Kakadu, western Arnhem Land and Nitmiluk (Katherine Gorge).

**Open forest and woodland**

Open forest and woodland support the greatest diversity of birds in the Park with many widely distributed and highly mobile species. The most widespread include white-bellied cuckoo-shrike (*Coracina papuensis*), mistletoebird (*Dicaeum hirundinaceum*), white-throated honeyeater (*Melithreptus albogularis*) and brown honeyeater (*Lichmera indistincta*). These regions are an important habitat of the scarce partridge pigeon.

The mainly nectar-feeding lorikeets, such as the rainbow and varied lorikeets (*Trichoglossus haematodus* and *Psitteuteles versicolor*), feed on various trees, particularly large-flowered eucalypts such as woollybutt and *Eucalyptus porrecta*. The mobile honeyeaters and friarbirds, a large family of 18 species, are important pollinators of the woodland trees. Cockatoos and other parrots and finches feed on tree and grass seeds.

Fires attract many birds which feed on disturbed animals. Others take advantage of access to the ground facilitated by fire (Woinarski 1990). The black kite (*Milvus migrans*) is common and often attracted to fires. Disturbed animals are also prey to the brown falcon (*Falco berigora*), black falcon (*Falco subniger*) and whistling kite (*Haliastur sphenurus*), while the grey butcherbird (*Cracticus torquatus*), magpie-lark (*Grallina cyanoleuca*), black-faced cuckoo-shrike (*Coracina novaehollandiae*), owls and nightjars, among others, hunt in the fire’s aftermath. Various seed-eaters, including the red-tailed black cockatoo (*Calyptorhynchus banksii*) feed on recently burnt ground.

**Wetlands**

The wetlands support more than 60 species of waterbirds. Herons, egrets and bittern (10 species), ibis and spoonbill (five species), ducks and geese (11 species), and darters and cormorants (five species) are all
well represented. There are also more than 15 species of migratory waders of the plover and dotterel families.

Up to two and a half million water birds have been estimated to congregate in Kakadu during the dry season between August and October. The greatest concentrations are on the Magela and Nourlangie floodplains (Morton et al. 1989). The magpie goose (Anseranas semipalmata) and wandering whistling-duck (Dendrocygna arcuata) are the most abundant.

Wetland birds are predominantly dry season migrants of which few species breed in large numbers in the Park. One which does breed in abundance is the comb-crested jacana (Irediparra gallinacea). Several species of egrets, herons, ibis and cormorants also breed locally. The breeding sites of brolgas in the Park are of regional significance.

Other wetland ducks include plumed whistling-duck (Dendrocygna eytoni), radjah shelduck (Tadorna radjah), green pygmy-goose (Nettapus pulchellus), grey teal (Anas gracilis) and Pacific black duck (Anas superciliosa), while several species of ibis, the royal spoonbill (Platalea regia) and yellow-billed spoonbill (Platalea flavipes) all arrive in the dry season. Little curlews (Numenius minutus), migrating from their breeding grounds in Siberia, arrive in large numbers in the late dry season to feed on the drier floodplains, departing at the onset of the rains. The striking black-necked stork (jabiru, Ephippiorhynchus asiaticus) has become a popular symbol of the Kakadu wetlands, indeed of the Top End generally. The yellow chat (Epthianura crocea), an uncommon bird throughout its discontinuous range, has narrow habitat requirements, preferring grassland on blacksoil plains.

Monsoon rainforests

Characteristic of these habitats are the orange-footed scrubfowl, rainbow pitta, grey whistler (Pachycephala simplex), little shrike-thrush (Colluricincla megarhyncha) and rose-crowned fruit-dove. The rainbow pitta feeds on invertebrates in the leaf litter.

Birds move seasonally between patches of rainforest (Kikkawa & Monteith 1980; Woinarski 1993). Rainforest fruits are eaten by many species. Three species, including the pied-imperial pigeon, feed exclusively on fruit.
Over 70% of rainforest plants produce small fleshy fruits, of which birds eat at least 43 different species (Russell-Smith & Dunlop 1987; Woinarski 1993).

Lowland and coastal rainforests support more species than those of sandstone habitats. Inhabitants include the little bronze-cuckoo (*Chrysococcyx minitillus*), green-backed gerygone (*Gerygone chloronotus*) and bar-shouldered dove (*Geopelia humeralis*). Coastal rainforest may share in common with mangrove habitats such species as grey whistler, red-headed honeyeater (*Myzomela erythrocephala*) and shining flycatcher (*Myiagra alecto*).

**Mangrove and estuarine habitats**

Mangrove habitats, which provide ample supplies of fish, shell-fish and crustaceans, support the mangrove gerygone (*Gerygone levigaster*), collared kingfisher (*Todiramphus chloris*), yellow white-eye (*Zosterops luteus*), striated heron (*Buto rides striatus*), white-breasted whistler (*Pachycephala lanioides*), chestnut rail, brahminy kite and broad-billed flycatcher (*Myiagra ruficollis*). Several species of coastal herons and egrets breed in these locations.

**Foreshore and beaches**

Nearly 40 species of birds are found along the coastal edge, among which the families Scolopacidae (sandpipers) and Charadriidae (plovers) are prominent. This congregation includes several sandpipers, a variety of godwits, curlews and knots, plovers and red-kneed dotterel (*Erythrogonys cinctus*), pied and sooty oystercatchers, as well as beach stone-curlew and whimbrel. Tides rise and fall up to 8 m, and shore birds feed in response to these tidal movements rather than a day-night routine. Ocean-going birds such as the brown booby (*Sula leucogaster*), great frigatebird (*Fregata minor*) and lesser frigatebird (*Fregata ariel*), the silver gull (*Larus novaehollandiae*) and up to 10 species of terns use this coastal region.

**The raptors**

These very mobile species generally range widely over the landscape. Kakadu has recorded all species of raptors found in Australia. Including the osprey (*Pandion haliaetus*), there are 24 species of raptors recorded in the
PLATE 6.1 Banded fruit-dove, a rarely seen visitor to monsoon vine forests (Ian Morris).

PLATE 6.2 Black cockatoo (Greg Miles).
PLATE 6.3 Spectacular aggregations of waterfowl assemble in Kakadu in the dry season (Greg Miles).

PLATE 6.4 Wandering whistling-ducks on the bank of a billabong (Greg Miles).
PLATE 6.5 One of Kakadu's most beautiful mammals, the restricted black wallaroo (Ian Morris).

PLATE 6.6 The newly described Kakadu dunnart (Martin Armstrong).
PLATE 6.7 Chequered rainbowfish (Greg Miles).

PLATE 6.8 Pig-nosed turtle – the South Alligator River is a stronghold for this restricted species (GE Schmida/Australian Nature Transparencies Photo Library).
PLATE 6.9 The tree-frog Litoria dahliai (Martin Armstrong).

PLATE 6.10 Kakadu's largest animal, the estuarine crocodile (Greg Miles).
PLATE 6.11 The exquisite Leichhardt's grasshopper (Ian Morris).

PLATE 6.12 An amazing 100 tonnes per hectare of soil is kept above ground in these giant termite mounds in the Park (Greg Miles).
Park, of which the whistling kite is the most common. The white-bellied sea-eagle (*Haliaeetus leucogaster*) feeds on fish and waterbirds, and nests in tall trees beside rivers and lowland monsoon rainforest. The wedge-tailed eagle (*Aquila audax*) takes most of its prey on the ground, including in its diet carrion, fish and waterbirds. The rare red goshawk (*Erithrostria radiatus*) is found in Kakadu and the Park is an important conservation area for this species (Brouwer & Garnett 1990). Other species of note in this group include square-tailed kite (*Lophosticini asura*), grey goshawk, black falcon, the scarce peregrine falcon (*Falco peregrinus*), and little-seen grey falcon (*Falco hypoleucos*).

**Nocturnal hunters**

The 13 species of nocturnal predatory birds in the Park comprise six owls (including southern boobook, *Ninox novaeseelandiae*), tawny frogmouth (*Podargus strigoides*), three nightjars, nankeen night heron and both bush stone-curlew (*Burhinus grallarius*) and beach stone-curlew. The rufous owl is associated mainly with lowland riparian rainforest, and the scarce grass owl is known from the South and East Alligator floodplains.

**6.4 Reptiles†**

**Crocodiles**

Both species of Australian crocodiles occur in Kakadu National Park. The estuarine or saltwater crocodile (*Crocodylus porosus*) inhabits coastal estuarine areas, tidal rivers, and also perennial and ephemeral freshwater reaches and billabongs. The freshwater crocodile (*Crocodylus johnstoni*) occurs in permanent freshwater habitats, particularly the upper reaches of streams that persist during the dry season as discontinuous billabongs.

The Australian population of the estuarine crocodile is now listed on Appendix 2 of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) to enable crocodile farming, the export of skins and some commercial use of wild-caught animals (Webb et al. 1984).

† Unless stated otherwise, scientific nomenclature in Sections 6.4 Reptiles and 6.5 Amphibians follows Cogger (1992).
Estuarine crocodiles breed throughout the year with a peak of nesting during the wet season. The nest consists of mounds of vegetation and mud near permanent water. Freshwater crocodiles nest in the dry season in sandy river banks where the eggs are buried.

Turtles

The pig-nosed turtle (*Carettochelys insculpta*) occurs in coastal rivers of southern Papua New Guinea, as well as in northern Australia, where it has been recorded from the Daly River, the South and East Alligator Rivers and the Victoria River. In Papua New Guinea it inhabits both estuarine and middle reaches of rivers. It has not been recorded from estuarine areas in Australian rivers but is found in freshwater pools in middle and upper river reaches. The upper reaches of the South Alligator River are lined with pandanus and riverine rainforest plants such as *Terminalia microcarpa*, *Ficus racemosa* and *Syzygium* spp., the fruits of which are eaten by the pig-nosed turtle. Though it is omnivorous, it is more herbivorous than carnivorous (Georges & Kennett 1989). Although fairly common where it occurs in both Australia and Papua New Guinea, it has limited distribution, and the South Alligator River in Kakadu represents a significant refuge for this species.

The northern snake-necked turtle (*Chelodina rugosa*) occurs across northern Australia. In Kakadu it is found from pools at the base of the escarpment to tidal reaches in the East and South Alligator rivers (Cogger 1973). It survives the dry season by aestivating underground (Kennett & Christian 1994). Its populations may be highest in floodplain billabongs and swamps (Legler 1982, Kennett 1994). It is carnivorous, feeding on crustaceans, other aquatic invertebrates and small fish (Kennett & Tory, in press).

The nesting strategy of the northern snake-necked turtle is unique. It represents a remarkable adaptation to the seasonally wet and dry climate and the vagaries of the ephemeral habitats this species is found in. It begins nesting in the late wet season, laying its eggs in flooded ground at the edge of floodplain waterholes. Embryonic development remains arrested until the water level drops and the ground dries. Incubation occurs during the dry season and hatchlings emerge at the start of the following wet season (Kennett et al. 1993a&b).
An unnamed species of *Chelodina* is found in pools on the sandstone plateau of Kakadu and Arnhem Land. It also occurs in the Kimberley region of Western Australia (Legler 1982).

The northern snapping turtle (*Elseya dentata*) is found in Queensland and in north and north-western Australia. In Kakadu it is typically found in sandy or rocky stretches of the Magela and South Alligator systems between the escarpment and the floodplains. It also occurs in pools on the sandstone plateau. It feeds chiefly on leaves, flowers and fruits that drop into the water (Kennett & Tory, in press).

The saw-shelled turtle (*Elseya latisternum*) has a wide distribution, including eastern coastal streams from Cape York to the Murray-Darling tributaries in New South Wales. In Kakadu it occurs in pools on the sandstone plateau complex and eats algae and crustaceans.

The northern yellow-faced turtle, *Emydura victoriae*, occurs across northern Australia. In Kakadu it is found in billabongs downstream from the escarpment (Legler 1982). It is omnivorous, and includes in its diet leaves, fruits and flowers which drop into the water.

Guinea (1990) records two species from Field Island in the north of Kakadu. These were the flatback sea turtle (*Natator depressus*, formerly known as *Chelonia depressa*) and the Pacific ridley sea turtle (*Lepidochelys olivacea*). Miles (1988) reports nesting on Field Island and West Alligator Head by the green sea turtle (*Chelonia mydas*) and loggerhead sea turtle (*Caretta caretta*) as well as the flatback sea turtle. Miles suggests that Field Island is a particularly important nesting site because it is free of mainland egg predators such as dingos, pigs and humans, although goannas are present.

**Lizards**

The 76 lizards known from the Park comprise 16 geckos, four legless lizards, 9 dragons, 11 monitors and 36 skinks. The introduced Asian house gecko has also been recorded in dwellings. Regional endemic species include the jewelled velvet gecko, Pamela’s gecko and the skink *Ctenotus coggeri*, all from the rugged sandstone country. The giant cave gecko (*Pseudothecadactylus lindneri*) is restricted to the sandstone of western Arnhem Land. Recently described endemics include the gecko
Diplodactylus occultus (King et al. 1982), and skinks Ctenotus gagudju and C. kurnbudj (Sadlier et al. 1985) from open forest, and Egernia arnhemensis (Sadlier 1990) from the escarpment. The goanna Varanus baritji appears to be restricted to rocky areas of Arnhem Land and extending west to the Adelaide River.

Other notable species are the rarely seen chameleon dragon (Chelosania brunnea) which ranges from the Kimberley to the Gulf of Carpentaria, the long-tailed rock monitor (Varanus glebopalma), Glauert’s rock monitor, Varanus glauerti, ring-tailed dragon (Ctenophorus caudicinctus), the gecko Heteronotia planiceps, and the gecko Diplodactylus immaculatus, first described in 1988 and known from semi-arid regions of central Queensland to Tennant Creek.

Several lizards have widespread ranges, including the arboreal, diurnal skink Cryptoblepharus plagiocephalus and Bynoe’s gecko (Heteronotia binoei), probably the most abundant gecko in the Park. These species are found over most of the continent. Geckos, mostly nocturnal, are most abundant in the escarpment and plateau region of Kakadu National Park. Found in this area are the jewelled velvet gecko, giant cave gecko, Pamela’s gecko, marbled velvet gecko (Oedura marmorata), Gehyra nana and several species of Diplodactylus.

The legless lizards known from Kakadu are Burton’s legless lizard (Lialis burtonis), found in sandstone plateau woodland and forest, the hooded scaly-foot (Pygopus nigriceps) and two species of Delma.

The conspicuous frilledneck lizard (Chlamydosaurus kingii) is most obvious during the wet season when it is most active. During the dry season it may also be found in burnt areas. It spends much of the dry season clinging to branches high in trees (Shine & Lambeck 1989).

Of the monitors, the sand goannas (Varanus gouldii and V. panoptes), are commonly seen in the open forest and woodland, and the water monitors (Varanus mertensi and V. mitchelli) near streams and billabongs. Varanus primordius and V. baritji (both endemic to the Top End) occur in Kakadu’s lowlands and the long-tailed rock monitor and Varanus glauerti are associated with sandstone country. The mangrove monitor is found along the estuaries.
<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Diplodactylus ciliaris</em></td>
<td>spiny-tailed gecko</td>
</tr>
<tr>
<td><em>Diplodactylus conspicillatus</em></td>
<td>fat-tailed gecko</td>
</tr>
<tr>
<td><em>Diplodactylus immaculatus</em></td>
<td></td>
</tr>
<tr>
<td><em>Diplodactylus occultus</em></td>
<td></td>
</tr>
<tr>
<td><em>Diplodactylus stenodactylus</em></td>
<td></td>
</tr>
<tr>
<td><em>Gehyra australis</em></td>
<td>northern dtella</td>
</tr>
<tr>
<td><em>Gehyra nana</em></td>
<td></td>
</tr>
<tr>
<td><em>Gehyra pamelas</em></td>
<td>Pamela's gecko</td>
</tr>
<tr>
<td><em>Hemidactylus frenatus</em></td>
<td>house gecko</td>
</tr>
<tr>
<td><em>Heteronotia binoei</em></td>
<td>Bynoe's gecko</td>
</tr>
<tr>
<td><em>Heteronotia planiceps</em></td>
<td></td>
</tr>
<tr>
<td><em>Nephrurus sheart</em>†</td>
<td>northern knob-tailed gecko</td>
</tr>
<tr>
<td><em>Oedura gemmata</em></td>
<td>jewelled velvet gecko</td>
</tr>
<tr>
<td><em>Oedura marmorata</em></td>
<td>marbled velvet gecko</td>
</tr>
<tr>
<td><em>Oedura rhombifer</em></td>
<td>zig-zag gecko</td>
</tr>
<tr>
<td><em>Pseudothecadactylus lindneri</em></td>
<td>giant cave gecko</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Legless lizards</strong></td>
<td></td>
</tr>
<tr>
<td><em>Delma borea</em></td>
<td></td>
</tr>
<tr>
<td><em>Delma tincta</em></td>
<td></td>
</tr>
<tr>
<td><em>Lialis burtonis</em></td>
<td>Burton's legless lizard</td>
</tr>
<tr>
<td><em>Pygopus nigriceps</em></td>
<td>hooded scaly-foot</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Dragon lizards</strong></td>
<td></td>
</tr>
<tr>
<td><em>Chelosania brunnea</em></td>
<td>chameleon dragon</td>
</tr>
<tr>
<td><em>Chlamydosaurus kingii</em></td>
<td>frilledneck lizard</td>
</tr>
<tr>
<td><em>Ctenophorus caudicinctus</em></td>
<td>ring-tailed dragon</td>
</tr>
<tr>
<td><em>Diporiphora albilabris</em></td>
<td></td>
</tr>
<tr>
<td><em>Diporiphora bennetti</em></td>
<td></td>
</tr>
<tr>
<td><em>Diporiphora bilineata</em></td>
<td>two-lined dragon</td>
</tr>
<tr>
<td><em>Diporiphora magna</em></td>
<td></td>
</tr>
<tr>
<td><em>Lophognathus gilberti</em></td>
<td></td>
</tr>
<tr>
<td><em>Lophognathus temporalis</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Monitor or goanna lizards</strong></td>
<td></td>
</tr>
<tr>
<td><em>Varanus baniiti</em></td>
<td>Glaeurt's rock monitor</td>
</tr>
<tr>
<td><em>Varanus glauerti</em></td>
<td>long-tailed rock monitor</td>
</tr>
<tr>
<td><em>Varanus glebopalma</em></td>
<td>Gould's or sand goanna</td>
</tr>
<tr>
<td><em>Varanus gouldii</em></td>
<td>mangrove monitor</td>
</tr>
<tr>
<td><em>Varanus indicus</em></td>
<td>Merten's water monitor</td>
</tr>
<tr>
<td><em>Varanus mertensi</em></td>
<td>Mitchell's water monitor</td>
</tr>
<tr>
<td><em>Varanus michelli</em></td>
<td>northern sand goanna</td>
</tr>
<tr>
<td><em>Varanus panoptes</em></td>
<td></td>
</tr>
<tr>
<td><em>Varanus primordius</em></td>
<td></td>
</tr>
<tr>
<td><em>Varanus timorensis</em></td>
<td>spotted tree monitor</td>
</tr>
<tr>
<td><em>Varanus tristis</em></td>
<td>black-headed goanna</td>
</tr>
</tbody>
</table>
Table 6.2 (continued)

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Skinks</strong></td>
<td></td>
</tr>
<tr>
<td><em>Carlia amax</em></td>
<td>two-spined rainbow skink</td>
</tr>
<tr>
<td><em>Carlia gracilis</em></td>
<td>slender rainbow skink</td>
</tr>
<tr>
<td><em>Carlia munda</em></td>
<td>striped rainbow skink</td>
</tr>
<tr>
<td><em>Carlia rufilatus</em></td>
<td>red-sided rainbow skink</td>
</tr>
<tr>
<td><em>Carlia triancantha</em></td>
<td>three-spined rainbow skink</td>
</tr>
<tr>
<td><em>Cryptoblepharus megastictus</em></td>
<td>spotted snake-eyed skink</td>
</tr>
<tr>
<td><em>Cryptoblepharus plagiopcephalus</em></td>
<td>arboreal snake-eyed skink</td>
</tr>
<tr>
<td><em>Ctenotus arnhemensis</em></td>
<td>Arnhem Land ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus borealis</em></td>
<td>northern ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus coggeri</em></td>
<td>Cogger's ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus decaneurus</em></td>
<td>ten-lined ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus essingtonii</em></td>
<td>Port Essington ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus gagudju</em></td>
<td>Kakadu ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus hilli</em></td>
<td>Hill's ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus inomatus</em></td>
<td>plain ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus kumbudj</em></td>
<td>Alligator Rivers ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus robustus</em></td>
<td>robust ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus spaldingi</em></td>
<td>Spalding's ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus stori</em></td>
<td>Storr's ctenotus</td>
</tr>
<tr>
<td><em>Ctenotus vertebralis</em></td>
<td>scant-striped ctenotus</td>
</tr>
<tr>
<td><em>Egermia arnhemensis</em></td>
<td>Arnhem Land egermia</td>
</tr>
<tr>
<td><em>Lerista karlschmidtli</em></td>
<td>Karl Schmidt's lerista</td>
</tr>
<tr>
<td><em>Lerista orientalis</em></td>
<td>eastern lerista</td>
</tr>
<tr>
<td><em>Lerista stylis</em></td>
<td>single-toed lerista</td>
</tr>
<tr>
<td><em>Menetia alanae</em></td>
<td>Alana's menetia</td>
</tr>
<tr>
<td><em>Menetia concinna</em></td>
<td>neat menetia</td>
</tr>
<tr>
<td><em>Menetia greyii</em></td>
<td>Grey's menetia</td>
</tr>
<tr>
<td><em>Menetia maini</em></td>
<td>Main's menetia</td>
</tr>
<tr>
<td><em>Morethia ruficaua</em></td>
<td>red-tailed snake-eyed skink</td>
</tr>
<tr>
<td><em>Morethia stori</em></td>
<td>Storr's snake-eyed skink</td>
</tr>
<tr>
<td><em>Notoscincus wotjulum</em></td>
<td>ornate snake-eyed skink</td>
</tr>
<tr>
<td><em>Proablepharus tenuis</em></td>
<td>slender snake-eyed skink</td>
</tr>
<tr>
<td><em>Gephyromorphus darwiniensis</em></td>
<td>Darwin skink</td>
</tr>
<tr>
<td><em>Gephyromorphus douglasi</em></td>
<td>Douglas's skink</td>
</tr>
<tr>
<td><em>Gephyromorphus isolepis</em></td>
<td>smooth-scaled skink</td>
</tr>
<tr>
<td><em>Tiliqua scincoides</em></td>
<td>common blue-tongued lizard</td>
</tr>
</tbody>
</table>

* Sources: Woinarski & Braithwaite (1991), updated by P Horner (NT Museum). Unless stated otherwise, scientific nomenclature follows Cogger (1992)
† Source: Couper & Gregson (1994)
The greatest diversity of lizards are found among the skinks (Table 6.2). They are most common in woodland habitats (Woinarski & Gambold 1992).

Snakes

Kakadu’s snakes are made up of 39 species from six families (Table 6.3).

Three species of sea-snakes have been recorded in the estuarine and tidal reaches of the rivers: Hardwick’s sea-snake (*Lapemis hardwickii*), the Darwin sea-snake (*Hydrelaps darwiniensis*) and Stokes’s sea-snake (*Astrotia stokesii*).

The ant-eating blind snake *Ramphotyphlops torelli* is one of the most common snakes recorded in the Park and is mainly found in rainforest habitats. There are six other blind snakes (Table 6.3) in the Park.

Pythons include the black-headed python (*Aspidites melanocephalus*), Children’s python (*Liasis childrei*), the Oenpelli python (*Morelia oenpelliensis*) restricted to the sandstone of Kakadu and Arnhem Land, and the carpet python, found mainly in rainforest. Both the olive and water pythons (*Liasis olivaceus* and *L. fuscus*) are common predators of rats, and occasionally waterfowl, on the sedgelands during the dry season.

Two file snakes have been recorded in Kakadu, the abundant Arafura file snake (*Acrochordus arafurae*), found in permanent freshwater billabongs, and the little file snake (*Acrochordus granulatus*) which inhabits estuarine regions and feeds on crabs and small fish. Arafura file snakes grow to 2 m in length and feed exclusively on fish, from small ones to barramundi or sleepy cod of about 1 kg in weight.

The Colubrid snakes are represented by eight species in Kakadu. The slaty-grey snake (*Stegonotus cucullatus*), common tree snake and brown tree snake are common and mostly found in rainforests, which support more species than do other habitats. The frog-eating keelback or freshwater snake (*Tropidonophis mairii*) may be found in both freshwater sites and coastal rainforest. Bockadam (*Cerberus rynchops*), Macleay’s water snake (*Enhydris polylepis*) and the white-bellied mangrove snake (*Fordonia leucobalia*) favour mangrove habitats where they feed on crustaceans and fish.
Table 6.3 Checklist of snakes of Kakadu National Park*

<table>
<thead>
<tr>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sea snakes</strong></td>
<td></td>
</tr>
<tr>
<td>Astrotia stokesii</td>
<td>Stokes's sea-snake</td>
</tr>
<tr>
<td>Hydrelaps darwiniensis</td>
<td>Darwin sea-snake</td>
</tr>
<tr>
<td>Lapemis hardwickii</td>
<td>Hardwick's sea-snake</td>
</tr>
<tr>
<td><strong>Blind snakes</strong></td>
<td></td>
</tr>
<tr>
<td>Ramphotyphlops grypus</td>
<td></td>
</tr>
<tr>
<td>Ramphotyphlops guentheri</td>
<td></td>
</tr>
<tr>
<td>Ramphotyphlops ligatus</td>
<td></td>
</tr>
<tr>
<td>Ramphotyphlops tovelli</td>
<td></td>
</tr>
<tr>
<td>Ramphotyphlops unguirostris</td>
<td></td>
</tr>
<tr>
<td>Ramphotyphlops wiedii</td>
<td></td>
</tr>
<tr>
<td>Ramphotyphlops yirrikalae</td>
<td></td>
</tr>
<tr>
<td><strong>Pythons</strong></td>
<td></td>
</tr>
<tr>
<td>Aspidites melanocephalus</td>
<td>black-headed python</td>
</tr>
<tr>
<td>Liasis childreni</td>
<td>Children's python</td>
</tr>
<tr>
<td>Liasis fuscus</td>
<td>water python</td>
</tr>
<tr>
<td>Liasis olivaceus</td>
<td>olive python</td>
</tr>
<tr>
<td>Morelia oenpelliensis</td>
<td>Oenpelli python</td>
</tr>
<tr>
<td>Morelia spilota</td>
<td>carpet python</td>
</tr>
<tr>
<td><strong>File snakes</strong></td>
<td></td>
</tr>
<tr>
<td>Acrochordus arafurae</td>
<td>Arafura file snake</td>
</tr>
<tr>
<td>Acrochordus granulatus</td>
<td>little file snake</td>
</tr>
<tr>
<td><strong>Colubrids</strong></td>
<td></td>
</tr>
<tr>
<td>Boiga irregularis</td>
<td>brown tree snake</td>
</tr>
<tr>
<td>Cerberus rynchops</td>
<td>bockadam</td>
</tr>
<tr>
<td>Dendrelaphis punctulata</td>
<td>common or green tree snake</td>
</tr>
<tr>
<td>Enhydris polyplepis</td>
<td>Macleay's water snake</td>
</tr>
<tr>
<td>Fordonia leucobalia</td>
<td>white-bellied mangrove snake</td>
</tr>
<tr>
<td>Myron richardsonii</td>
<td></td>
</tr>
<tr>
<td>Stegonotus cucullatus</td>
<td>slaty-grey snake</td>
</tr>
<tr>
<td>Tropidonophis mainii</td>
<td>keelback or freshwater snake</td>
</tr>
<tr>
<td><strong>Elapids</strong></td>
<td></td>
</tr>
<tr>
<td>Acanthophis praelongus</td>
<td>northern death adder</td>
</tr>
<tr>
<td>Demansia atra</td>
<td>black whip snake</td>
</tr>
<tr>
<td>Demansia olivacea</td>
<td>olive whip snake</td>
</tr>
<tr>
<td>Demansia papuensis</td>
<td></td>
</tr>
<tr>
<td>Demansia torquata</td>
<td>(unconfirmed by specimen)</td>
</tr>
<tr>
<td>Furina ornata</td>
<td>moon snake</td>
</tr>
<tr>
<td>Oxyuranus scutellatus</td>
<td>taipan</td>
</tr>
<tr>
<td>Pseudechis australis</td>
<td>king brown snake</td>
</tr>
<tr>
<td>Pseudonaja nuchalis</td>
<td>western brown snake</td>
</tr>
<tr>
<td>Rhinoplocephalus pallidiceps</td>
<td>northern small-eyed snake</td>
</tr>
<tr>
<td>Simoselaps semifasciatus roperi</td>
<td>northern shovel-nosed snake</td>
</tr>
<tr>
<td>Suta punctata</td>
<td>little spotted snake</td>
</tr>
<tr>
<td>Vermicella multifasciata</td>
<td>northern bandy bandy</td>
</tr>
</tbody>
</table>

The most diverse group of snakes in Kakadu are the Elapids. They are venomous front-fanged snakes including the king brown snake (*Pseudechis australis*), western brown snake (*Pseudonaja nuchalis*), taipan (*Oxyuranus scutellatus*), several species of Demansia (whip snakes), northern bandy bandy (*Vermicella multifasciata*) and the northern death adder (*Acanthophis paelongus*).

### 6.5 Amphibians

Twenty-five frogs from three families are known from Kakadu. Most notable is the uncommon large carpenter frog (*Megistolotis lignarius*),

**Table 6.4 Checklist of frogs of Kakadu National Park**

<table>
<thead>
<tr>
<th>Family Myobatrachidae</th>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Crinia bilingua</em></td>
<td>bilingual frog (ratchet frog)</td>
</tr>
<tr>
<td></td>
<td><em>Limnodynastes convexiusculus</em></td>
<td>marbled frog</td>
</tr>
<tr>
<td></td>
<td><em>Limnodynastes ornatus</em></td>
<td>ornate burrowing frog</td>
</tr>
<tr>
<td></td>
<td><em>Megistolotis lignarius</em></td>
<td>carpenter frog</td>
</tr>
<tr>
<td></td>
<td><em>Notaden melanoscaphus</em></td>
<td>northern spadefoot toad</td>
</tr>
<tr>
<td></td>
<td><em>Uperoleia arenicola</em></td>
<td>Jabiru toadlet</td>
</tr>
<tr>
<td></td>
<td><em>Uperoleia inundata</em></td>
<td>floodplains toadlet</td>
</tr>
<tr>
<td></td>
<td><em>Uperoleia lithomoda</em></td>
<td>stonemason toadlet</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Family Hylidae</th>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Cyclorana australis</em></td>
<td>giant burrowing frog</td>
</tr>
<tr>
<td></td>
<td><em>Cyclorana longipes</em></td>
<td>long-footed frog</td>
</tr>
<tr>
<td></td>
<td><em>Litoria bicolor</em></td>
<td>northern dwarf tree-frog</td>
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<tr>
<td></td>
<td><em>Litoria caerulea</em></td>
<td>green tree-frog</td>
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<tr>
<td></td>
<td><em>Litoria coplandi</em></td>
<td>Copland's rock frog</td>
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<tr>
<td></td>
<td><em>Litoria dahlii</em></td>
<td>Dahl's aquatic frog</td>
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<tr>
<td></td>
<td><em>Litoria dorsalis</em></td>
<td>javelin frog (dwarf rocket frog)</td>
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<tr>
<td></td>
<td><em>Litoria inermis</em></td>
<td>Peters's frog</td>
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<tr>
<td></td>
<td><em>Litoria meiriana</em></td>
<td>rock-hole frog</td>
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<tr>
<td></td>
<td><em>Litoria nasuta</em></td>
<td>rocket frog</td>
</tr>
<tr>
<td></td>
<td><em>Litoria pallida</em></td>
<td>pale frog</td>
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<tr>
<td></td>
<td><em>Litoria personata</em></td>
<td>masked cave-frog</td>
</tr>
<tr>
<td></td>
<td><em>Litoria rothii</em></td>
<td>brown tree-frog (Roth's tree-frog)</td>
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<tr>
<td></td>
<td><em>Litoria rubella</em></td>
<td>desert tree-frog (red tree-frog)</td>
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<td></td>
<td><em>Litoria tornieri</em></td>
<td>Tornier's frog</td>
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<tr>
<td></td>
<td><em>Litoria wotjulumensis</em></td>
<td>wotjulum frog</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Family Microhylidae</th>
<th>Scientific name</th>
<th>Common name</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><em>Sphenophryne adelpe</em></td>
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</tbody>
</table>
restricted to sandstone country from western Arnhem Land to the Kimberley. Other rock-dwelling endemics of the Top End and Kimberley sandstone regions found in Kakadu, frequenting crevices and moist sites near small perennial streams, are Copland's rock frog (*Litoria coplandi*), *Litoria meiriana*, and the rarely seen *L. personata*. Most frogs occur on the seasonal wetlands and especially in the wooded fringes of the floodplains (Friend & Cellier 1990).

Several frogs, such as the ornate burrowing frog (*Limnodynastes ornatus*), spend the dry season deep in the soil, emerging in the rainy season to breed. Others, including the brown tree-frog (*Litoria rothii*) and marbled frog (*Limnodynastes convexiusculus*), survive the dry season in muddy sites, and require deep pools for breeding. *Uperoleia inundata* is a very common termite-eating frog.

Up to 15 species of frog are known from rainforests in the Park. One species, *Sphenophryne adelpha*, prefers moist escarpment rainforest, though it occurs in a range of other habitats.

### 6.6 Fish

Fifty-five species of freshwater fish have been recorded from Kakadu National Park, with several of these usually being found in a marine or estuarine environment. This remarkable diversity makes the region the most species-rich in Australia. Of these 55 species, probably about 40 could be called true freshwater fishes, because they do not use the sea or estuarine areas for breeding.

Several conspicuous Park species such as the tarpon (*Megalops cyprinoides*) and barramundi (*Lates calcarifer*) spawn in the sea but juveniles migrate upstream to live in fresh water. A number of Northern Territory estuarine fishes may visit or spend part of their lives in fresh water, aided by the 8 m tidal range, and land-locked populations of 'marine' fishes can occur.

Many more marine and estuarine species will be recorded for Kakadu waters as the coast and river estuaries are sampled in the future.

Thirty-three of these freshwater species are widespread across northern Australia and 13 have a broad but disjunct distribution, with many of
### Table 6.5 Checklist of freshwater fish in Kakadu National Park†

<table>
<thead>
<tr>
<th>Family</th>
<th>Species</th>
<th>EA</th>
<th>SA</th>
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<th>WR</th>
<th>KR</th>
<th>MR</th>
<th>Habitat</th>
<th>Status</th>
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<td>Osteoglossidae – saratoga</td>
<td>Scleropages jardini</td>
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<td>FLH</td>
<td>2,5</td>
</tr>
<tr>
<td>Ariidae – fork-tailed catfish</td>
<td>Arius berneyi</td>
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<tr>
<td></td>
<td>Arius leptaspis</td>
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<tr>
<td></td>
<td>Arius graeffi</td>
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<tr>
<td></td>
<td>Arius midgleyi</td>
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<tr>
<td>Plectognathidae – eel-tailed catfish</td>
<td>Andostomus dahli</td>
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<tr>
<td></td>
<td>Neosilurus ater</td>
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<tr>
<td></td>
<td>Neosilurus hyrtlilii</td>
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<tr>
<td></td>
<td>Porochilus rendahlil</td>
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<tr>
<td></td>
<td>Porochilus obesi</td>
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<tr>
<td>Melanotaenidae – rainbowfish</td>
<td>Melanotaenia exquisita</td>
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<tr>
<td></td>
<td>Melanotaenia nigrans</td>
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<tr>
<td></td>
<td>Melanotaenia splendida</td>
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<tr>
<td></td>
<td>Melanotaenia trifasciata</td>
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</tr>
<tr>
<td>Pseudomugilidae – blue-eyes</td>
<td>Pseudomugil gertrudae</td>
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<tr>
<td></td>
<td>Pseudomugil tenellus</td>
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</tr>
<tr>
<td>Atherinidae – hardyheads</td>
<td>Craterocephalus stercusmuscarum</td>
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<tr>
<td></td>
<td>Craterocephalus marianae</td>
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<tr>
<td>Centropomidae – barramundi</td>
<td>Lates calcarifer</td>
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<td>FLH</td>
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<tr>
<td>Chandidae – glassfish</td>
<td>Ambassis agrammus</td>
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<tr>
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<td>Ambassis macleayi</td>
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</tr>
</tbody>
</table>

†The status codes used are: F = Freshwater, LH = Lowland habitat, FLH = Floodplain habitat, FL = Marine habitat.
Table 6.5 (continued)

<table>
<thead>
<tr>
<th>Family</th>
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<th>MR</th>
<th>Habitat</th>
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<td>Amiataba percoidees</td>
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<tr>
<td>Hephaestus fuliginosus</td>
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<tr>
<td>Leioptotherapon unicolor</td>
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<td>Syncomistes bulleri</td>
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<td>Apogonidae – mouth almighty</td>
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<td>Toxotidae – archerfish</td>
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<td>Toxotes lorentzi</td>
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<td>Toxotes chatareus</td>
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<td>Scatophagidae – scats</td>
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<td>Scatophagus argus</td>
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<td>Selenotoca multifasciata</td>
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<td>Liza alata</td>
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<td>Liza tade</td>
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<td>Kurtidae – nurseryfish</td>
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<td>Gobiidae – gobies</td>
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<td>Glossogobius aureus</td>
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<tr>
<td>Glossogobius sp.</td>
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<td>Eleotridae – gudgeons</td>
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<td>Oxyleotris nullipora</td>
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<td>Oxyleotris selheimi</td>
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<td>Mogurnda mogurnda</td>
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<tr>
<td>Ophiocara piocephala</td>
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<td>Soleidae – soles</td>
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<td>Aseraggodes kluzeinieri</td>
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<td>Brachirus selheimi</td>
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<td>LH</td>
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</table>

† Table derived from unpublished data supplied by R Pidgeon, Environmental Research Institute of the Supervising Scientist, Jabiru NT, and updated by H Larson (NT Museum). Primary sources include Bishop et al. (1986), Bywater (1989), Larson (1987), Larson and Martin (1990).

EA East Alligator Rivers system; SA South Alligator River system; WA West Alligator River system; WR Wildman River system; KR Katherine River; MR Mary River. * Present; or, in that category; ? presence in river system uncertain but likely; – not recorded; F Floodplain; L Lowlands; H Headwaters. 1 Distribution restricted to the Top End; 2 Broad but disjunct distribution across northern Australia; 3 Broad distribution across northern Australia; 4 Insufficient information on distribution and abundance; 5 Locally common and abundant; 6 Species rarely sighted or restricted within Kakadu.
these latter species occurring sporadically across the Top End, Cape York and southern Papua New Guinea. There are no fish species restricted to the Park itself, but several with patchy distributions (such as the banded rainbowfish, *Melanotaenia trifasciata*; coal grunter, *Hephaestus carbo*; and Midgley’s grunter, *Pingalla midgleyi*) are found only in particular localities within the Park.

Five species of freshwater fish have been recorded to date only in the Top End. These are the exquisite rainbowfish (*Melanotaenia exquisita*), Mariana’s hardyhead (*Craterocephalus marianae*), sharp-nosed grunter (*Syncoristes butleri*), black anal-fin grunter (*Pingalla midgleyi*), and a new species of gudgeon (*Hypseleotris* sp.) recently collected from the upper Katherine River in Kakadu. There are no introduced fish in Kakadu.

Some freshwater fishes are restricted to particular habitats within the Park, and others undertake considerable seasonal movement. For example, the exquisite rainbowfish is usually abundant in swift rocky creeks and cascade pools in upland country. The Katherine River gudgeon (*Hypseleotris* sp.) appears to be restricted entirely to certain parts of that river system, and may be found congregating along *Pandanus* lined banks.

The early wet season migrations taken on by many species of fish can be quite spectacular, as millions upon millions of fish recolonise lowland creeks and billabongs. Fish may move downstream from perennial refuge areas, or travel upstream from the lower reaches; and feeding activity increases. Some species, such as the various rainbow fishes and glassfish, can form dense schools that look like a solid mass.

Lowland habitats provide excellent breeding and nursery areas, but only in the short term. As the wet season ends, water levels drop and conditions change, so that fish must again move to their dry season refuges. During all these migrations, piscivorous fishes such as long toms, gudgeons and barramundi may operate in ambush, hiding among snags or under overhanging tree roots.

Not all fish leave the lowland habitats during the dry season; many fish can be encountered virtually year-round in the Park. These include chequered rainbowfish, glassfish, fork-tailed and eel-tailed catfish, gudgeons and grunters.
6.7 Insects

Introduction

The invertebrate fauna of Kakadu is diverse but only a few groups are well understood (Andersen 1990). It is estimated that over 10,000 insect species occur in the Park and many of these are undescribed.

Insects rarely attract the attention they deserve in conservation management programs (Samways 1994). Insects have a poor public image, and indeed are often considered merely as pests. However, if the aim of conservation is to maintain biological diversity, then attention should focus on insects because they constitute more than 90% of all animal species (Wilson 1988). Similarly, if the aim of conservation is to maintain the ecological integrity of ecosystems, then attention should also focus on insects because of their fundamental roles in ecosystem structure and function (Wilson 1987). These comments are particularly true for the Kakadu region, where, compared with savannas elsewhere in the world, the mammalian fauna is relatively impoverished and insects assume a number of ecological roles played by vertebrates elsewhere. For example, insects are the major herbivores in the Kakadu region, as they are throughout northern Australia, and, for many plant species, they are also the major agents of seed dispersal (Andersen & Lonsdale 1990).

Insects have another important role in the conservation management of Kakadu: as indicators of the biological impacts of human disturbance. In particular, insects have been used extensively to monitor the impacts of uranium mining in and around Kakadu, especially in relation to potential contamination of aquatic systems (Humphrey et al. 1995; Faith et al. 1995), but also as a measure of the success of ecosystem restoration following mining (Andersen 1993a; Andersen et al. 1995).

Overview of insect research in Kakadu

Almost nothing was known of the insect fauna of the Kakadu region until the surveys of 1972/3 conducted as part of the Alligator Rivers Region fact-finding study (CSIRO 1973). Although 65,000 specimens
representing 4500 species were collected, it was recognised that coverage was very incomplete. These collections, however, established the fauna as being extremely rich and diverse. The major findings were as follows:

*Termites* (*Isoptera*): 49 species were collected, including up to 10 considered possibly endemic to the Kakadu region, such as the undescribed species of *Nasutitermes* which builds large mounds on outliers of the Arnhem Land plateau.

*Grasshoppers* (*Orthoptera*): 91 species (6 eumastacids, 4 pyrgomorphids and 78 acridids) were collected, 39 (43%) of which were undescribed, and 17 previously unknown to science.

*Beetles* (*Coleoptera*): 24 000 specimens were collected, but only 11 500 had been processed at the time of the report. These yielded about 850 species from 55 families.

*Flies* (*Diptera*): about 1000 species from 50 families were collected, which was considered to be about half the total regional fauna.

*Butterflies and moths* (*Lepidoptera*): over 1500 species were collected, including 63 species of butterflies. It was estimated that at least 60% of the species had not previously been recorded from the NT, and that 40% of these were new to science.

*Wasps* (*Hymenoptera*): more than 500 species from over 200 genera were recorded, but it was noted that this represents a mere fraction of the regional fauna.

Since this pioneering survey, a substantial body of research (Cranston 1991, Wells 1991, Suter 1992, Hawkins 1993) has been conducted on aquatic insects as part of environmental monitoring by the Environmental Research Institute of the Supervising Scientist (ERISS). In addition, CSIRO has conducted detailed studies of selected terrestrial insects, notably ants (Greenslade 1985; Andersen 1991a&b, 1992a, 1993a), termites (Braithwaite et al. 1988), grasshoppers (AN Andersen & LM Lowe, unpublished) and mud-nesting wasps (Naumann 1983). However, virtually no further work has been done on Kakadu’s remaining terrestrial insect fauna.
Overview of selected insect groups

The following section provides a faunistic overview of the best-known insect groups. However, except for dragonflies, this is based on limited surveys and is therefore very incomplete. In most cases it covers probably less than half of the species actually occurring in Kakadu. It should also be pointed out that these insect groups have been poorly surveyed throughout northern Australia, making it impossible to evaluate the regional significance of the Kakadu fauna.

*Mayflies (Ephemeroptera)*

A total of 24 species from 13 genera are known from the Kakadu region (Table 6.6). Most of the species, and several genera, are undescribed. Many of the species are rare or have highly restricted distributions.

**Table 6.6 Generic listing of mayflies (Ephemeroptera) recorded from Kakadu National Park (Suter 1992)†**

<table>
<thead>
<tr>
<th>Leptophlebiidae</th>
<th>Baetidae</th>
<th>Caenidae</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Atalophlebia</em></td>
<td><em>Baetis</em></td>
<td><em>Tasmanocoenis</em> (7)</td>
</tr>
<tr>
<td><em>Bibulmena</em> (2)</td>
<td><em>Centroptilum</em></td>
<td>undescribed genus</td>
</tr>
<tr>
<td><em>Jappa</em> (2)</td>
<td><em>Cloeon</em></td>
<td></td>
</tr>
<tr>
<td><em>Thraulus</em> (2)</td>
<td>undescribed genera (3)</td>
<td></td>
</tr>
<tr>
<td>undescribed genera (2)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† When a genus is represented by multiple species, this is indicated in parentheses

*Dragonflies (Odonata)*

Taxonomically, the dragonflies are probably the best known group of insects in Kakadu (CSIRO 1973, Watson 1980, Watson & Abbey 1980, Hawkins 1993). Watson and Abbey (1980) list 93 species of Odonata (36 Zygoptera and 57 Anisoptera; Table 6.7) from 54 genera known from the Top End of the Northern Territory, most of which occur in Kakadu. Except for two species, this represents the entire NT dragonfly fauna. Several additional species have since been recorded from the Kakadu region (Watson et al. 1991).

Two dragonfly species, *Hemigomphus magela* and *Austrocordulia territoria*, are particularly noteworthy (Watson 1980). Both are known only from streams associated with the Arnhem escarpment, and both have Bassian (cool-temperate) affinities. All other known species of *Hemigomphus*, for example,
occur in coastal and montane streams of eastern Australia (Watson et al. 1991), with closely related genera occurring in southwestern Australia and in South America. Species of *Nannophlebia*, *Lithosticta*, *Pseudagrion* and *Nososticta* also appear to be endemic to streams draining the Arnhem Land plateau.

Table 6.7 Generic listing of dragonflies (Odonata) recorded for the Top End of the Northern Territory by Watson & Abbey (1980)†

<table>
<thead>
<tr>
<th>ZYGOPTERA</th>
<th>ANISOPTERA</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Protoneuridae</strong></td>
<td><strong>Gomphidae</strong></td>
</tr>
<tr>
<td><em>Austrosticta</em> (2)</td>
<td><em>Antipodogomphus</em> (2)</td>
</tr>
<tr>
<td><em>Eurydicta</em> (2)</td>
<td><em>Austrogomphus</em> (2)</td>
</tr>
<tr>
<td><em>Isosticta</em></td>
<td><em>Hemigomphus</em></td>
</tr>
<tr>
<td><em>Notosticata</em> (7)</td>
<td><em>Ictinogomphus</em></td>
</tr>
<tr>
<td><strong>Coenagrionidae</strong></td>
<td><strong>Aeshnidae</strong></td>
</tr>
<tr>
<td><em>Aciagrion</em></td>
<td><em>Anaciaeschna</em></td>
</tr>
<tr>
<td><em>Agriocnemis</em> (3)</td>
<td><em>Anax</em> (2)</td>
</tr>
<tr>
<td><em>Archibasis</em></td>
<td><em>Austrogynacantha</em></td>
</tr>
<tr>
<td><em>Argiocnemis</em></td>
<td><em>Gynacantha</em> (2)</td>
</tr>
<tr>
<td><em>Australagrion</em> (2)</td>
<td><em>Hemianax</em></td>
</tr>
<tr>
<td><strong>Corduliidae</strong></td>
<td><strong>Corduliidae</strong></td>
</tr>
<tr>
<td><em>Ceriagrion</em></td>
<td><em>Austrocordulia</em></td>
</tr>
<tr>
<td><em>Ischnura</em> (3)</td>
<td><em>Hemicordulia</em> (3)</td>
</tr>
<tr>
<td><em>Pseudagrion</em> (5)</td>
<td><em>Macromia</em></td>
</tr>
<tr>
<td><em>Xanthagrion</em></td>
<td><em>Pentathemis</em></td>
</tr>
<tr>
<td><strong>Megapodagrionidae</strong></td>
<td></td>
</tr>
<tr>
<td><em>Podopteryx</em></td>
<td></td>
</tr>
<tr>
<td><strong>Lestidae</strong></td>
<td><strong>Rhopalocera</strong></td>
</tr>
<tr>
<td><em>Austrolestes</em></td>
<td></td>
</tr>
<tr>
<td><em>Indolestes</em> (2)</td>
<td></td>
</tr>
<tr>
<td><em>Lestes</em></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† When a genus is represented by multiple species, this is indicated in parentheses

**Termites (Isoptera)**

Termite mounds are a conspicuous feature of the Kakadu landscape, and are a popular tourist attraction (Andersen & Jacklyn 1993). The termites themselves are seldom seen because of their cryptic habits, nesting and foraging predominantly in soil and in wood. Species are often classified according to diet, feeding on either organic matter in soil, or living on dead
wood, on leaf litter, or on dead grass. Litter-feeders and grass-eaters ('harvesters') build most of the mounds that adorn the Kakadu landscape (Andersen & Jacklyn 1993). The spectacular mounds of the cathedral termite, *Nasutitermes triodiae*, are among the largest in the world, attaining heights up to 7 m (Plate 6.12). Other conspicuous mounds are those of *Coptotermes acinaciformis* at the base of trees, and of an undescribed species of *Amitermes* which is endemic to floodplain margins of the Kakadu region. Termite mounds are important nesting sites for many of Kakadu's important reptile, bird and mammal species, including the rare hoodie parrot (Braithwaite 1990). In a broadscale survey of termites in Kakadu, Braithwaite et al. (1988) recorded 50 species from 16 genera (Table 6.8), which probably represents about half the total Kakadu fauna. The number of species is comparable with that occurring in African savannas, except that Kakadu has a lower richness of harvester species (Andersen & Lonsdale 1990).

**Table 6.8 Generic listing of termites** (Isoptera) **recorded in Kakadu by Braithwaite et al. (1988)†**

<table>
<thead>
<tr>
<th>Mastotermidae</th>
<th>Termitidae</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Mastotermes</em></td>
<td><em>Ahamiltermes</em></td>
</tr>
<tr>
<td><strong>Kalotermitidae</strong></td>
<td><em>Amitermes</em> (6)</td>
</tr>
<tr>
<td><em>Cryptotermes</em></td>
<td><em>Australitermes</em></td>
</tr>
<tr>
<td><em>Neotermes</em> (2)</td>
<td><em>Drepanotermes</em></td>
</tr>
<tr>
<td><strong>Rhinotermidae</strong></td>
<td><em>Invastermes</em></td>
</tr>
<tr>
<td><em>Coptotermes</em></td>
<td><em>Microcerotermes</em> (6)</td>
</tr>
<tr>
<td><em>Heterotermes</em> (3)</td>
<td><em>Nasutitermes</em> (6)</td>
</tr>
<tr>
<td><em>Schedorhinotermes</em> (2)</td>
<td><em>Occultitermes</em></td>
</tr>
<tr>
<td></td>
<td><em>Termes</em> (13)</td>
</tr>
<tr>
<td></td>
<td><em>Tumulitermes</em> (4)</td>
</tr>
</tbody>
</table>

† When a genus is represented by multiple species, this is indicated in parentheses

**Grasshoppers (Orthoptera)**

Grasshoppers are probably the most important grazing animals in Kakadu, but this has not been directly studied. Grasshoppers are major grazers even in African savannas supporting large populations of herbivorous mammals (Andersen & Lonsdale 1990). A broadscale survey of grasshoppers in Kakadu recorded 58 species, belonging to 47 genera and five families (Table 6.9). This did not include the spectacular, bright red and blue Leichhardt's
grasshopper, *Petasida epiphiggera* (Pyrgomorphidae), which is restricted to sandstone country of the Arnhem Land escarpment and plateau, except for a small population at Keep River National Park (Lowe 1995).

**Table 6.9 Generic listing of grasshoppers (Orthoptera) recorded during a broadscale survey of Kakadu (data from Andersen et al. 1995)†**

<table>
<thead>
<tr>
<th>ACRIDIDAE</th>
<th>Cyrtacanthacridinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acridinae</td>
<td>Nomadacris (2)</td>
</tr>
<tr>
<td>Acrida</td>
<td>Valanga (2)</td>
</tr>
<tr>
<td>Aiolopus</td>
<td>Oxyiinae</td>
</tr>
<tr>
<td>Caledia</td>
<td>Bermiella</td>
</tr>
<tr>
<td>Froggattina</td>
<td>Dapemia</td>
</tr>
<tr>
<td>Gastrimargus</td>
<td>Tolgadia</td>
</tr>
<tr>
<td>Heteropternis</td>
<td>EUMASTACIDAE</td>
</tr>
<tr>
<td>Locusta</td>
<td>Geckonima</td>
</tr>
<tr>
<td>Pycnostictus</td>
<td>unidentified genera (5)</td>
</tr>
<tr>
<td>Catantopinae</td>
<td>PYRGOMORPHIDAE</td>
</tr>
<tr>
<td>Adlappa</td>
<td>Attractomorpha</td>
</tr>
<tr>
<td>Aretza</td>
<td>TETRIGIDAE</td>
</tr>
<tr>
<td>Aretzina</td>
<td>unidentified genus</td>
</tr>
<tr>
<td>Caloptilla</td>
<td>TETTIGONIIDAE</td>
</tr>
<tr>
<td>Coryphistes</td>
<td>Conocephalinae</td>
</tr>
<tr>
<td>Curpilidia</td>
<td>Conocephalus</td>
</tr>
<tr>
<td>Erythroppomala</td>
<td>Decticinae</td>
</tr>
<tr>
<td>Goniaea (2)</td>
<td>Chlorobialis</td>
</tr>
<tr>
<td>Goniaeoida</td>
<td>Listrocellinae</td>
</tr>
<tr>
<td>Happarana</td>
<td>unidentified genus</td>
</tr>
<tr>
<td>Macrazelota</td>
<td>Meconemitaiae</td>
</tr>
<tr>
<td>Macrocarca</td>
<td>unidentified genus</td>
</tr>
<tr>
<td>Rectitrophis</td>
<td>Phaneropterinae</td>
</tr>
<tr>
<td>Stenocatantops (2)</td>
<td>Caedicia (3)</td>
</tr>
<tr>
<td>Xantarriaria</td>
<td>Polichne</td>
</tr>
<tr>
<td>Xypechthia</td>
<td></td>
</tr>
<tr>
<td>Zebratula</td>
<td></td>
</tr>
<tr>
<td>undescribed genera (5)</td>
<td></td>
</tr>
</tbody>
</table>

† When a genus is represented by multiple species, this is indicated in parentheses

**Non-biting midges (Diptera: Chironomidae)**

A total of 116 chironomid species from 44 genera are known from the Kakadu region (Table 6.10). Most of these are undescribed and known from nowhere else. The fauna includes four new genera.
Table 6.10 Generic listing of non-biting midges (Diptera: Chironomidae) recorded from Kakadu (Cranston 1991)†

<table>
<thead>
<tr>
<th>Tanypodinae</th>
<th>Chironominae</th>
<th>Chironominae (cont.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ablabesmyia (2)</td>
<td>Chironomus (10)</td>
<td>Stenochironomus (2)</td>
</tr>
<tr>
<td>Clinotanyus</td>
<td>Cladopelma (2)</td>
<td>Stictochironomus</td>
</tr>
<tr>
<td>Coelopynia</td>
<td>Cladotanytarsus (5)</td>
<td>Tanytarsus (14)</td>
</tr>
<tr>
<td>Djalmabatistia</td>
<td>Conoehironomus (3)</td>
<td>Xenochironomus (2)</td>
</tr>
<tr>
<td>Fittkauiimyia</td>
<td>Cryptoehironomus (3)</td>
<td>Zavreliella</td>
</tr>
<tr>
<td>Larsia</td>
<td>Dicrotendipes (17)</td>
<td>unidentified genera (4)</td>
</tr>
<tr>
<td>Nilotanytus</td>
<td>Harischia</td>
<td></td>
</tr>
<tr>
<td>Paramerina</td>
<td>Kiefferulus (3)</td>
<td></td>
</tr>
<tr>
<td>Procladus</td>
<td>Microehironomus</td>
<td></td>
</tr>
<tr>
<td>Tanytus</td>
<td>Parachironomus (3)</td>
<td></td>
</tr>
<tr>
<td>Tienemannimyia</td>
<td>Paratanytarsus (2)</td>
<td></td>
</tr>
<tr>
<td>Orthocladinae</td>
<td>Paraehadopelma (3)</td>
<td></td>
</tr>
<tr>
<td>Cricotopus (2)</td>
<td>Paratendipes (2)</td>
<td></td>
</tr>
<tr>
<td>Nanocladius</td>
<td>Polypedilum (10)</td>
<td></td>
</tr>
<tr>
<td>Parakiefferiella</td>
<td>Rheotanytarsus (3)</td>
<td></td>
</tr>
<tr>
<td>Parametricnemus</td>
<td>Robackia</td>
<td></td>
</tr>
<tr>
<td>Rheocricotopus</td>
<td>Skusella (2)</td>
<td></td>
</tr>
<tr>
<td>Tienemannimyia</td>
<td>Sterpellina</td>
<td></td>
</tr>
</tbody>
</table>

† When a genus is represented by multiple species, this is indicated in parentheses

Caddis-flies (Trichoptera)

A total of 105 species of caddis-flies from 22 genera are known from Kakadu, with three particularly rich genera (Oecetis, Orthotrichia and Ecnomus) contributing half of these (Table 6.11). Biogeographically, these species are typical of a central Torresian fauna (A Wells, pers. comm.).

Table 6.11 Generic listing of caddis-flies (Trichoptera) recorded from Kakadu (Wells 1991)†

<table>
<thead>
<tr>
<th>Anisocentropus</th>
<th>Hydroptila</th>
<th>Oxyethira (4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asmicridea</td>
<td>Leptocerus</td>
<td>Polyplectopus</td>
</tr>
<tr>
<td>Cheumatopsyche (4)</td>
<td>Leptorussa</td>
<td>Tinodes</td>
</tr>
<tr>
<td>Chimarra (4)</td>
<td>Nyctiophylax</td>
<td>Triaenodes (7)</td>
</tr>
<tr>
<td>Ecnomina (7)</td>
<td>Oecetis (20)</td>
<td>Tricholeiochiton (2)</td>
</tr>
<tr>
<td>Ecnomus (16)</td>
<td>Orphninotrichia</td>
<td>Triplectides (2)</td>
</tr>
<tr>
<td>Heliopsyche (2)</td>
<td>Orthotrichia (17)</td>
<td>unidentified genus</td>
</tr>
<tr>
<td>Hellyethira (9)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

† When a genus is represented by multiple species, this is indicated in parentheses

206
Ants (Hymenoptera: Formicidae)

A total of 309 ant species from 48 genera have been recorded from Kakadu (Table 6.12). The savanna woodlands and open forests are particularly rich in species, with up to 100 species or more occurring in a single hectare (Andersen 1992a). The composition of the savanna fauna is similar to that of the arid zone, being dominated by highly active and aggressive species of *Iridomyrmex*, and including numerous

Table 6.12 Generic listing of ant species (Hymenoptera: Formicidae) recorded from Kakadu, based on collections by AN Andersen (unpublished)†

<table>
<thead>
<tr>
<th>Myrmeciinae</th>
<th>Myrmicinae (cont.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myrmecia</td>
<td>Machomyrma</td>
</tr>
<tr>
<td>Pseudomyrmecinae</td>
<td>Meranoplus (18)</td>
</tr>
<tr>
<td>Tetraponera (3)</td>
<td>Monomorium* (32)</td>
</tr>
<tr>
<td>Ponerinae</td>
<td>Oligomyrmex (2)</td>
</tr>
<tr>
<td>Amblyopone</td>
<td>Pheidole (29)</td>
</tr>
<tr>
<td>Anochetus (5)</td>
<td>Pheidologeton</td>
</tr>
<tr>
<td>Bothroponera (8)</td>
<td>Podomyrma (3)</td>
</tr>
<tr>
<td>Diacamma</td>
<td>Quadrirn ruma (4)</td>
</tr>
<tr>
<td>Discothyrea</td>
<td>Solenopsis* (5)</td>
</tr>
<tr>
<td>Ectomomyrmex</td>
<td>Strumigenys</td>
</tr>
<tr>
<td>Hypoponera (4)</td>
<td>Tetramorium* (7)</td>
</tr>
<tr>
<td>Leptogenys (7)</td>
<td></td>
</tr>
<tr>
<td>Mystrium</td>
<td></td>
</tr>
<tr>
<td>Odontomachus (5)</td>
<td></td>
</tr>
<tr>
<td>Platythyrea (2)</td>
<td></td>
</tr>
<tr>
<td>Rhytidoponera (21)</td>
<td></td>
</tr>
<tr>
<td>Trachymesopus</td>
<td></td>
</tr>
<tr>
<td>Dorylinae</td>
<td></td>
</tr>
<tr>
<td>Aenictus (3)</td>
<td></td>
</tr>
<tr>
<td>Cerapachyiinae</td>
<td></td>
</tr>
<tr>
<td>Cerapachys (9)</td>
<td></td>
</tr>
<tr>
<td>Sphinctomyrmex (3)</td>
<td></td>
</tr>
<tr>
<td>Myrmicinae</td>
<td></td>
</tr>
<tr>
<td>Aphaenogaster</td>
<td></td>
</tr>
<tr>
<td>Cardiocondyla (3)</td>
<td></td>
</tr>
<tr>
<td>Crematogaster (7)</td>
<td></td>
</tr>
<tr>
<td>Glamyromyrmex (2)</td>
<td></td>
</tr>
</tbody>
</table>

† When a genus is represented by multiple species, this is indicated in parentheses,

(* includes introduced species)
species of *Camponotus*, *Melophorus*, *Monomorium* and *Pheidole* (Andersen 1992a, 1993b; Andersen & Patel 1994). Community structure is strongly influenced by fire, with high fire frequency favouring arid-adapted taxa and promoting local species richness (Andersen 1991b). Arid-adapted taxa are generally absent from monsoon rainforests, where ant abundance and richness are both far lower than in savanna. Although most of the rainforest taxa occurring in humid rainforests of Queensland are absent, the monsoon forest fauna still includes a significant number of rainforest specialists with South-east Asian affinities (Andersen 1992b; Andersen & Reichel 1994).

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7

Fire management

Jeremy Russell-Smith

7.1 Fire management

The need for fire management

Fire is one of the most important management issues in Kakadu National Park, and is central to ideas promoted both by traditional owners and biologists concerning the need to maintain a diversity of habitat conditions for species with differing requirements. It is also, for many visitors, a highly contentious issue. Given these different perspectives, and given also the central role fire management plays in habitat management in the Park generally, this chapter focuses exclusively on burning. All other management issues are considered in the next chapter.

Visitors to the Park often remark adversely on the amount of burning they have witnessed, both within Kakadu, and elsewhere in northern Australia. Thus, most tourists visit the Park in the relatively cool early- to mid-dry season months (May–July), corresponding to the time of year when the majority of management burning is undertaken. As well, many visitors evidently equate such burns with the potentially catastrophic fires of temperate south-eastern and south-western Australia. In contrast to
temperate Australia, however, fires in the monsoonal tropics are carried in
the ground layer, typically as grass fires. As well, most vegetation in the
region is highly resilient to even frequent fires, and faunal studies
emphasise the need for maintaining a diversity of unburnt and burnt
habitats for species with different requirements.

Controlled fire management in the region has both a long tradition, and
is essential for restricting damaging wildfires from burning over large
areas where fire exclusion measures are impractical, or where habitats
are fire-sensitive. As well, recent Park management experience indicates
that wildfires lit inadvertently by visitors, particularly those spreading
from campfires lit in the late dry season and from roadsides, are now a
major problem. The key to effective fire management, therefore, is to:

- educate visitors concerning the potential effects of fire; and
- undertake controlled burning at times of the year when fires will be
  of low intensity.

Fire in the monsoon tropics

In the monsoon tropics of northern Australia, fire is employed as a
management tool by Aboriginal people, by pastoralists, and by National
Park managers generally. Its widespread usage in the region relates to
the marked alternation of wet and dry seasons, and the effect such
seasonality has on the growth and flammability of vegetation,
particularly the grasses.

Much of the Top End region of the Northern Territory is mantled by
open forest and woodland communities comprising a grassy
understorey. In the wet season, principally November through April,
the grass layer undergoes spectacular development, with some species
attaining 3 m or more in height. With the drying out of soils at the end
of the rainy season, grasses begin to cure. By the end of May many grass
species, but especially annuals, are completely cured over large areas.
This grassy component provides for a ready fuel which, with
increasingly dry and flammable conditions as the dry season progresses,
poses a significant risk to fire-sensitive habitat and species, property,
and pastoral interests.

In contrast to forested areas of southern Australia, however, where
serious conflagrations are associated with fires in tree canopies
Fire management

(ie 'crown fires'), fires in the tropical forest and woodland savannas are ground-borne. This is mostly a consequence of the fact that, unlike their southern 'fire-promoting' relatives, the leaves of tropical eucalypts contain only small quantities of highly combustible, volatile oils. As such, tropical savanna fires are generally of much lower intensity, and pose relatively little risk to human life.

Management objectives

As outlined in the most recent Plan of Management (ANPWS 1991) the main objectives of fire management in the Park are as follows:

• protect life and property within and adjacent to the Park;
• maintain, as far as practicable, traditional bining [Aboriginal] burning regimes within the Park;
• maintain biodiversity;
• promote research into the fire sensitivity of environments and species;
• provide for the identification and protection of sensitive environments and species;
• maintain community education and interpretation programs covering the role of fire in Kakadu;
• minimise the spread of fire from the Park to adjoining land;
• minimise the spread of fire into the Park from adjoining land; and
• monitor the effectiveness of Park fire management programs.

As well as these objectives it is recognised that, through its direct influence on habitat, fire management plays a critical role in conservation of native flora and fauna generally.

Past and present fire regimes

In the above list of management objectives it is indicated that fire management will continue to be undertaken employing traditional Aboriginal burning regimes. To understand what is meant by traditional burning regimes, and to appreciate why such practice generally satisfies the requirements for conservative fire management, the historical and contemporary patterns of burning are explored here in some detail.

The natural fire regime

Natural fires (ie fires not lit by people) occur from October through to December as a consequence of lightning strikes associated with the dramatic electrical storms of the new wet season. This is the season called Gunumeleng (see Seasonal Calendar in chapter 2). Given that rain does not always accompany such storms, the resulting fires potentially may be intense. Such fires are well documented from the Park and from the Murgonella region, to the north of Kakadu, where former forestry practice involved an attempt to exclude all fires. This is the fire regime which was operative in the region before the arrival of people, more than 50,000 years ago. How frequent and extensive such fires were in the pre-human landscape is simply unknown.

Traditional Aboriginal burning practices

Fire was, and still is, a very important management tool for Aboriginal people – its use attuned to the climate, vegetation and fauna. Management of food resources, for example by burning cured grasses and encouraging regrowth (‘green pick’) for target animal species, especially macropods (ie kangaroos and wallabies), was only one of the objectives. Fires were employed directly as a hunting stratagem; for clearing rank grasses and undergrowth to make travel easier; for signalling, and for specific spiritual and cultural obligations. Fire was precluded from some areas whereas, in other places, there was a requirement to burn an area before entering. The purification roles of fire and smoke were, and still are in many areas, extremely important to Aboriginal people – for example, in mortuary rites. The Aboriginal concept of using fire to ‘clean the country’ may thus be understood in various contexts. In traditional Aboriginal society membership of a land-owning group (ie the clan) provided individuals both with rights to exploit, and responsibilities towards caring for, and managing land, most demonstrably through the controlled use of fire.

Beginning with short, dry spells in the wet season, gudjewg, burning was undertaken progressively throughout the year as clans travelled
through their estates. Fires lit early in the dry season were patchy and small in extent, increasing in size and intensity as grasses cured with the progression of the season. In the early dry season fires are self-extinguishing in the evening, given relatively high soil moisture levels, dew, and patchiness of cured grasses. Vegetation associated with drainage lines and floodplains may still not have been burnt at this time given the uncured state of most species. As well, it is evident that, in some areas at least, protective burning was undertaken on the margins of rainforest patches and other spiritually significant sites.

From about August onwards, however, fires may burn all night and through areas previously burnt earlier in the season. In the Kakadu region this is from about the time that *andjalen* (the Darwin woollybutt, *Eucalyptus miniata*) and *anrebel* (the Darwin stringybark, *Eucalyptus tetrodonta*) have finished flowering – the hot time of year *binging* people call *gurring*. Burning was necessarily undertaken at this time with circumspection. In the late dry season such fires, if not carefully directed onto recently burned areas or other fire-protected situations, may burn for days, consuming the plant resources required to feed prey species and people alike. In this context it is interesting to note that, from an assessment of nineteenth century northern Australian explorers' diaries, Braithwaite (1991) found that most reported Aboriginal burning occurred in the cool months of the mid-year, and markedly less at the very hot time in September.

One result of this controlled use of fire over much of the landscape was that the potential for widespread human-lit, intense late dry season fires would have been markedly diminished. How the frequency of such late season fires might compare with those ignited by lightning, however, is unknown. A second feature of the traditional fire regime is that it created a mosaic of unburnt, early burnt, and late burnt patches. Such a burning mosaic enhances habitat diversity which, as discussed later, is essential for maintaining suites of animal species with different requirements.

**Recent fire practice**

With a major reduction and redistribution of the regional Aboriginal population over the past 100 years associated with the advent of Europeans, traditional burning practices have been disrupted greatly. The effectiveness of such practices depended on highly mobile clans
ranging throughout the regional landscape. Changes in fire regime were associated also with the introduction of pastoralism; fires tended to be lit mainly in areas favoured by grazing water buffalo (eg floodplains and adjacent lowlands), and also later in the season associated with mustering activities. Collectively, these conditions probably resulted in a marked increase in intense and extensive late dry season fires. Extensive late dry season wildfires in sandstone escarpment and plateau areas apparently increased dramatically in frequency from the 1940s associated with the depopulation from that time (Lucas & Russell-Smith 1993).

**Contemporary practice**

By attempting to re-establish (as far as practicable) traditional Aboriginal burning patterns, contemporary Park practice 'aims to reduce the frequency, extent and intensity of wildfires within the Park and to protect species and habitats particularly sensitive to fire' (ANPWS 1986, 39). A practical implication of adopting the traditional fire management model is that considerable effort must be given to breaking up grassy fuels in the early-mid dry season, in effect to create a mosaic of burnt and unburnt patches across the landscape. As such, staff undertake a concentrated program of burning along roadsides, around campgrounds, and in the vicinity of fire-sensitive habitats such as rainforest patches, as soon as grasses cure sufficiently to carry fire. For remote areas out of reach of four-wheel drive vehicles, aerial ignition is extensively used employing small helicopters. In most years, burning begins in earnest in May and is largely completed, at least for plateau and lowland woodland savannas, by mid-July. Floodplain burning, on the other hand, is maintained throughout the dry season given that many areas remain moist late into the year.

A second practice, undertaken only in limited situations to date, has been to employ early wet season burns to reduce the density of tall annual grasses, especially *Sorghum intrans*. This species, which typically grows to over 3 m, provides one of the main woodland grass fuels, especially in disturbed situations. Early wet season burns eliminate both the standing fuel and new shoots, apparently with little impact on perennial grasses. Although clearly of practical utility for fire protection in limited situations, the effects of wet season burns on flora and fauna over extensive areas have yet to be assessed.
Fire management

Published data suggest that more than half the lowland area of Kakadu is burnt each year (Braithwaite & Estbergs 1985; Press 1988). These estimates are likely to somewhat inflate the extent of burning, however, based on an as yet unfinished study examining the distribution of fires in Kakadu between 1980–1994, interpreted from LANDSAT imagery. Although incomplete, these data indicate that the average annual extent of burning over this 15 year period more realistically lies between 40–45%.

Given the evident need to restrict typically intense wildfires in the latter part of the dry season, a more useful measure of the success or otherwise of the management-imposed fire regime is the proportion of burning which is undertaken in the early part of the year. Three studies relevant to the 1980s were undertaken by ANCA staff and its consultants. Each of these studies examined the relationship of early to late dry season burning in different portions of Kakadu National Park using LANDSAT satellite imagery.

Through the 1980s, the incidence of late dry season fires was widespread (Table 7.1). In two studies (Day 1985; Graetz 1990), late dry season fires were markedly more prevalent than early dry season burns in respective study areas over all years examined. In the third study (Press 1988), this pattern was demonstrated for three of the six years examined, in both Kakadu National Park Stages One and Two. On the positive side, this latter study demonstrated the effectiveness of early dry season burning in reducing the incidence of intense late dry season fires. Day (1985) also demonstrated that some severe late dry season fires were emanating from outside the Park, particularly from the south-east.

These data, and the growing concerns of Park staff, were instrumental in bringing about a modified operational approach to fire management in the early 1990s.

Increased funding was made available for aerial ignition in an attempt to provide a more flexible burning program concentrating early on in the burning season. Flexibility was extended also by the switch from using fixed-wing aircraft to more manoeuvrable (and cheaper) helicopters. Increased emphasis has been placed on fuel reduction in plateau and escarpment terrain with a view to providing increased protection for relatively fire-sensitive sandstone rainforest, heath, and
Table 7.1 Proportion of parts of Kakadu National Park burnt by early dry season (EDS) and late dry season (LDS) fires over the years 1980–1989, in three studies employing LANDSAT imagery

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<td>Plateau open forest (6%)</td>
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cypress pine communities. Though these new procedures have been in place only for a few years, the fire regime has seen a somewhat remarkable and reassuring shift to one now dominated by fires lit early in the year (Russell-Smith 1994). Such success demonstrates a real capacity to control fire regimes on and within the Park boundaries. The challenge for the future is to develop effective, sensitive means for managing habitats through the conservative use of fire.

7.2 Fire and vegetation

Most plant species and vegetation types in Kakadu National Park are well adapted to even frequent burning as a consequence of interactions with fire extending over some millions of years, well before the arrival of Aboriginal people at least 50,000 years ago. Thus, for example, many woody savanna species possess attributes such as thick protective bark, or the capacity to regenerate from woody tissues held at or below ground level, if aerial stems are killed.

Herbaceous species may evade both dry season aridity and burning through the annual habit; their whole life cycle, including production of next year’s seeds, completed in the wet season. Alternatively, herbaceous perennials commonly persist through the dry season as underground tubers, bulbs, and the like; as such, they are unaffected by burning.

Relatively fire sensitive vegetation, on the other hand, includes monsoon rainforest patches, stands of cypress pine (*Callitris intratropica*), and heath communities of the sandstone escarpment and plateau. The key word here is *relatively*, since these communities are quite tolerant of occasional, perhaps even frequent, low intensity fires. For example, low intensity fires early in the dry season will die out at rainforest patch margins given the absence of fire-promoting grasses, and high moisture content of rainforest litter. Their susceptibility to burning increases markedly, however, under an intense, late dry season burning regime.

Recent studies, both in Kakadu and elsewhere in the Top End of the Northern Territory, demonstrate clearly that monsoon rainforest (Russell-Smith 1984, 1985; Russell-Smith & Bowman 1992; Bowman 1994) and cypress pine communities (Bowman & Panton 1993) are being severely damaged under the modern burning regime of frequent, intense late dry season fires.

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It is probable also that the vegetation structure of open forest and woodland savanna communities is likewise being affected, albeit less dramatically, by recurrent late season fires. In a study of a particularly intense late season fire in Kakadu National Park, significant stem mortality of some woodland species was reported (Lonsdale & Braithwaite 1991). In another study, also undertaken in Kakadu National Park, it was found that, for pooled site data, the mid-storey of eucalypt forest and woodland study sites was effectively missing. These observations were interpreted as reflecting the influence of the contemporary fire regime (Braithwaite & Estbergs 1985). It may be anticipated also that recruitment of seedlings and juveniles of other species is similarly affected (eg the palm, Gronophyllum ramsayi).

While the above discussion relates broadly to the lowland savanna woodlands and open forests, particular management issues concern burning escarpment and plateau communities, and riverine floodplains. These issues are spelt out briefly below.

**Escarpmant and plateau**

Growing mostly on sandstone-derived substrates, the vegetation of the escarpment and plateau comprises extensive areas of relatively fire-sensitive rainforest, heath and cypress pine communities, as well as more fire-tolerant eucalypt woodland. Vegetation studies (eg Russell-Smith 1984; Bowman 1994; Bowman & Panton 1993) and Park management experience demonstrate unequivocally that plant communities (ie habitats) on the sandstone have received massive fire impact in recent times; such observations are borne out by satellite monitoring studies (eg Day 1985).

The major problem for fire management in the escarpment and plateau is that the Park adjoins a largely uninhabited tract of country (western Arnhem Land) that receives little fire management in the present day. As such, in the mid to late dry season, uncontrolled fires driven by predominantly dry south-easterly winds, if unchecked, may burn into the Park on 100 km+ fronts, over distances of many hundreds of kilometres. For recent times available satellite imagery records such extensive late dry season fires as occurring in 1972, 1982, 1984 and 1987.

Until as recently as 1991, Park staff were able to do little to address this problem; the availability of increased funding and helicopters has
changed all that. Now, burning is undertaken from as early in the dry season as possible, targeting the open sand plains which support eucalypt woodland; vegetation on the sandstone itself is left unburnt as much as possible. By burning strategically as little as 17% of the escarpment and plateau in 1992, and around 15% in 1993, with the great majority burnt early in the season, large fires bearing down on the Park have mostly been kept at bay.

**Floodplains**

Comprising mostly open herbaceous communities and fringing paperbark (*Melaleuca*) forests, floodplains currently present the major challenge for fire management in Kakadu. The problem is essentially one of fuel load. Up until the turn of the last century it is realistic to consider that Aboriginal people progressively burnt much of the floodplains, especially through the late dry season when hunting and foraging effort was concentrated on floodplain resources (Lucas & Russell-Smith 1993). From the turn of the century on, fuel loads would have been increasingly grazed down by huge herds of Asian water buffalo which came to roam (and eventually significantly modify) these plains. With the demise of large numbers of buffalo through the 1980s as part of the national BTEC program, grassy and cyperaceous fuels are again building up.

Current practice is to burn floodplain margins as early as possible, so as to reduce the possibility of fires later in the season exiting from floodplains or, conversely, entering from surrounding savanna woodlands. This program is undertaken each year using helicopters, but also by ground staff driving around floodplain margins and burning as they go. Such burning is essentially very labour intensive as it requires staff to go back time and time again, burning a little more on each visit as the floodplain slowly dries.

In floodplain areas which dry out only late in the season, the problem is one of critical timing given that hot, but slow moving fires can burn on the humic soil surface while grass cover may still be green and moist. Paperbarks and other woody species with superficial root systems are particularly susceptible to being killed by such fires. Further, in the absence of rain or substantial previously burnt areas to act as firebreaks, such fires are virtually unstoppable. In 1992 and 1993 about a third of
floodplains were burnt early in the season. Such burning in 1992 did not stop a severe, late dry season humic fire from burning most of an entire floodplain system from its inland extremity to the coast, over a distance of some 50 km. With a build-up in floodplain fuels we may anticipate more such fires into the future.

7.3 Fire and fauna

Knowledge of the intimate relationship between fire, plants and animals lies at the heart of traditional Aboriginal hunting strategies. Such strategies involve not only the flushing of game, but also habitat manipulation to provide for the specific requirements of target game species. An obvious example here is burning undertaken in a variety of habitats to cater for the individual requirements of different macropod species.

Recent faunal research in Kakadu National Park has focused on the relationship of specific animal groups to different fire regimes, but particularly the impact of late dry season burns. For example, in studies of the effects of fire regime on the distribution and abundance of lizard species, it has been found that different species evidently are favoured under different regimes (Braithwaite 1987; Trainor & Woinarski 1994). Thus, some species were observed to be fire-sensitive, others were unaffected, and others still were observed to favour areas burnt by intense, late dry season fires. These authors draw the conclusion that a range of fire regimes is required for conservation of the lizard fauna.

Similarly, in a study of the bird fauna based on the Munmarlary fire plots outlined below, Woinarski (1990) found that bird species exhibited clear responses to different burning treatments. He found that substantial numbers of species are attracted to recently-burnt areas, especially granivores and ground-feeding omnivores and carnivores. Indeed, given that tropical open forests and woodlands are effectively fire-prone environments, he observes that most species utilising this habitat are nomadic and take advantage of recent fires. Whereas species diversity was greatest on unburnt shrubby sites, only two species censused (red-backed fairy-wren, white-throated honeyeater) showed clear preference for unburnt plots. Such species evidently persist by dispersing to unburnt sites as these arise.
PLATE 7.1 Floodplain margins are burnt early in the dry season, and then progressively onto the plains as they dry out. Traditional burning of country is undertaken in many areas of the Park (Diane Lucas).

PLATE 7.2 Contemporary habitat management in the Park aims to impose a mosaic of burnt and unburnt patches over the landscape. Helicopters are widely used, particularly in more remote areas (Greg Miles).
Plate 7.3 Fires, particularly late in the dry season, are often dramatic but, unlike in parts of southern Australia, are invariably ground-borne and pose little risk to human life. Black kites are a common sight on fire fronts, hunting for insects and other small prey (Jean-Paul Ferrero/AUSCAPE).

Plate 7.4 Management of fire-sensitive habitats is an important goal. Here a controlled burn is being lit around the margin of a lowland rainforest patch to protect it from potentially destructive fires later in the season (Jeremy Russell-Smith).
PLATE 7.5 Long-term fire research has been undertaken at two experimental sites in Kakadu. At the Munmarlary sites some plots have been protected from fire for over 20 years. The photo contrasts vegetation burnt annually (foreground) to the development of a dense mid-canopy in the unburnt vegetation (background) (Jeremy Russell-Smith).

PLATE 7.6 Fires late in the dry season can burn over extensive areas. Here a slow-moving late dry season floodplain fire consumes all in its path, including the roots of living trees. Such fires may burn for months until finally extinguished by the drenching rains of the wet season (Jeremy Russell-Smith).
FIGURE 7.1 LANDSAT MSS satellite image of Kakadu National Park, October 1990, showing areas of recently burnt vegetation as black tones. Such imagery is being used to reconstruct the fire history of Kakadu National Park over the years 1980 to the present (ANCA).
Woinarski (1990) also suggests that the decline of granivorous species such as the partridge pigeon and the threatened Gouldian finch (both of which occur in Kakadu), may be related in part to the shift to late dry season fires. Such hot fires, he notes, probably destroy most of the grass seeds which these species depend on.

A third study, also conducted on the Munmarlary fire plots, involved the response of ground-foraging ant species to different fire regimes (Andersen 1991). This study, as with those of Braithwaite and Woinarski outlined above, notes that the habitat requirements of ants in the open forests and woodlands are best met by a range of fire regimes. However, it is important to remember also that many faunal species are denizens of relatively fire-sensitive habitats, for example rainforest patches (Kikkawa & Monteith 1980; Woinarski 1988).

As with vegetation studies, few data are currently available for effects of fire on fauna in lowland floodplain, and sandstone escarpment and plateau habitats.

7.4 Fire research

Munmarlary fire experiment

An important experimental study of the influence of fire regime on open forest and woodland savanna vegetation is established at Munmarlary, in Stage Two of Kakadu National Park. Experimental plots were established in 1972. The experiment was designed to test for floristic and structural changes in vegetation resulting from four separate fire regimes: annual early dry season burning (May–June); biennial early dry season burning; annual late dry season burning (August–October); and complete protection from fire.

The experimental design consists of the four fire treatments applied to separate one hectare plots laid out in three replicate blocks. The experiment continues to be maintained by staff from the Conservation Commission of the Northern Territory (CCNT) and ANCA.

Results from this study to date (Hoare et al. 1980; Bowman et al. 1988) indicate that, with complete protection from fire, dense understoreys develop in both open forest and woodland. However, after 13 years only slight structural differences were observed in burnt treatments, and
no marked floristic change was observed under any fire regime. Other published studies based on the Munmarlary experimental plots comprise studies of the responses of birds (Woinarski 1990), ants (Andersen 1991), and epiphytic orchids (Cook 1991).

The general applicability of the results of the Munmarlary study has been questioned, however, as the experimental design itself is seen to have flaws:

- early dry season burning treatments involve ensuring complete burns, as opposed to patchy, variable burning as generally observed under natural conditions (Lonsdale & Braithwaite 1991); and

- small sizes of plots not allowing for acceleration of intense fires (Lonsdale & Braithwaite 1991); small target area for, and relatively large distance (5 km) from, potentially successional rainforest taxa (Woinarski 1990; Lonsdale & Braithwaite 1991).

Despite these criticisms, it is evident from the results of the Munmarlary experiment that: open forest and woodland species are highly resilient (persistent), even in the face of intense, annual burning; and that structural, though not necessarily floristic, development will occur in the absence of fire. These data reinforce the view that the open forest and woodland savannas are highly adapted to burning.

Also of importance for the undertaking of such experimental studies is the finding of Bowman et al. (1988) that clear interpretation of the response of open forest and woodland vegetation to different fire regimes is made difficult by complex interactions between vegetation, fire regime, and patchy site conditions (eg soils). Thus, the long-term effects of different experimental fire regimes probably are best assessed by following changes on initially well inventoried, individual plots through time.

**Ongoing fire research**

Monitoring the extent and seasonality of fires has been shown to be very useful for identifying contemporary burning patterns (Table 7.1). This work is continuing with detailed satellite-based fire histories now available for all of Kakadu from 1980. It is expected that these data will be used to examine broad-scale effects of past and current burning on vegetation in the Park. As well, the CSIRO Division of Wildlife and
Ecology has been undertaking a multi-disciplinary, landscape-scale investigation of the effects of fire on vegetation and fauna at the Kapalga Research Station within Kakadu National Park. Using 12 research compartments, each approximately 15 km² in size and comprising a drainage catchment, researchers are exploring the effects of four fire regimes (each with three replicate treatments), much as in the Munmarlary fire experiment outlined above.

The fire treatments used in the Kapalga study comprise: early annual dry season burning; progressive burning from early in the dry season, followed by a series of fires as vegetation dries out downslope; late annual burning; and a natural regime where no human-lit fires are applied. To help interpret the effects of these four regimes, attention is being given also to quantifying fire behaviour (e.g., rates of spread, intensity, flame height).

In contrast to the Munmarlary experimental design the use of such large compartments will enable researchers to assess the effects of individual regimes on fauna given that the lifetime range of movements of most species (except some birds and large mammals) appears to be included within one compartment. While some of the problems of interpretation inherent in the Munmarlary study will apply to this study also (especially interacting site and fire effects, and assumptions concerning the generality of annual fires), it is envisaged this research will contribute substantially to better understanding of lowland forest and woodland ecology in Kakadu.

The most recent Plan of Management (ANPWS 1991) also identifies specific habitats where the effects of fire require further research and monitoring. These include escarpment and sandstone plateau communities, and floodplain vegetation and paperbark forests. As well, the development of appropriate methods for protecting fire sensitive communities such as monsoon rainforests and other vegetation types which, in the past, have been subject to destructive wildfires, is seen as a priority.

References


Fire management


8

Management considerations

Peter Wellings

8.1 Introduction

Kakadu is managed in accordance with the prescriptions of the National Parks and Wildlife Conservation Act 1975 and the terms of agreements under which Aboriginal Land within the Park is leased by its Aboriginal traditional owners to the Director of National Parks and Wildlife. It is managed jointly by the Director of National Parks and Wildlife and the Aboriginal traditional owners through a Board of Management. Management of the Park aims to conform to internationally accepted principles underlying the definition and management of national parks. The management of Kakadu also takes into account the ownership and continuing occupation of land in the Park by Aboriginal people.

Aboriginal significance

The contemporary Aboriginal owners of much of Kakadu are the direct descendants of people who have lived in the region for between 40 000 to 60 000 years. The present day Aboriginal traditional owners of land in the Park require that they have the opportunity to both maintain their
cultural traditions, including traditional responsibility for management of their land, and to pursue contemporary interests.

Kakadu National Park is also a community based conservation project where it is intended that indigenous land owners have the opportunity to participate fully in the management of their lands for conservation purposes (Hill & Press 1994). The concept of the 'joint management' of land for conservation purposes by professional conservation managers and indigenous land owners is regarded by the Australian Nature Conservation Agency as an important initiative and a concept that is fundamental to the successful management of Kakadu.

**National and international significance**

The significance of Kakadu's cultural and natural heritage is recognised by the inclusion of the Park estate on the list of World Heritage properties established under the international Convention Concerning the Protection of the World Cultural and Natural Heritage (the World Heritage Convention). Stage One of Kakadu National Park was included in the list in October 1981, the first Australian property to be listed. In December 1987, Stage Two was added to the list and in December 1992 the entire Park estate (including Stage Three) was consolidated as a single entry on the list. Kakadu National Park is one of only seventeen sites across the world listed for both their natural and cultural values. As a signatory to the World Heritage Convention, Australia has an on-going obligation to ensure that the world heritage values of Kakadu are protected. Regular reports are provided to the World Heritage Committee regarding management of the Park and the status of the property.

The importance of Kakadu's wetlands and waterfowl habitats were recognised in 1980 (Stage One) and 1989 (Stage Two) by the listing of these areas under the Convention on Wetlands of International Importance (the Ramsar Convention). The whole of Kakadu is also included on the Register of the National Estate kept by the Australian Heritage Commission. The National Estate is defined as 'those places, being components of the natural environment of Australia, or the cultural value of Australia, that have aesthetic, historic, scientific, or social significance or other special value for future generations, as well as for the present community'.

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Regional economic significance

Kakadu is a major Australian tourism icon. Expenditure on visits to Kakadu National Park accounts for more than 25% of all tourism expenditure in the Northern Territory (Knapman 1990) and the Park is considered to be an important attraction which also sustains and supports visitation to other parts of Australia.

Government at all levels in Australia is committed to promoting tourism as a job-creating growth industry and this is particularly so in the Northern Territory. Knapman (1990) found that Kakadu is a key tourist destination whose existence has caused a substantial expansion in the NT economy and estimated that in 1990 annual tourist expenditure within Kakadu alone was in the order of $AUD 30m. The Northern Territory Government’s tourism development agency, the Northern Territory Tourist Commission, is committed to achieving continuing growth in tourism and expects that Kakadu National Park will continue to be a major drawcard for tourists to the Top End of the Territory (Northern Territory Tourist Commission 1994).

8.2 The Park estate

Aboriginal ownership and Park lease arrangements

Much of the Park estate is owned by its Aboriginal traditional owners under the provisions of the Aboriginal Land Rights (Northern Territory) Act 1976 (see Figure 8.1).

On 3 November 1978 the Kakadu Aboriginal Land Trust leased three areas of land to the Director for the purposes of a national park ‘for the use, benefit, and enjoyment of all Australians’. This was the first occasion that Aboriginal Land within Australia was specially leased to a nature conservation agency for the purposes of joint management of the land for conservation. On 27 March 1991 a revised lease agreement with the Kakadu Aboriginal Land Trust and a new lease for land granted to the Jabiluka Aboriginal Land Trust were signed.

These leases contain special provisions to provide for:

- a commitment to world standard management procedures;
- the maintenance of traditional occupation (residency) and usage rights;
- training programs for traditional owners;
Management considerations

FIGURE 8.1 Land tenure in Kakadu National Park.
• a commitment to providing employment opportunities for Aboriginal people;
• support for Aboriginal business enterprises;
• annual rental payments;
• benefits from Park revenue.

A substantial area of land within the southern part of the Park is currently subject to land claim by traditional owners from the Jawoyn community. It is expected that if title to this land is granted to the claimants it will ultimately be leased to the Director under arrangements similar to those outlined above.

Other land within the Park

Land within Kakadu National Park that is not Aboriginal land is vested in the Director of National Parks and Wildlife. It has been the continuing policy of the Australian Nature Conservation Agency that the organisation's commitment to liaison and consultation with Aboriginal people regarding the management of the Park extends over the whole Park area, not just Aboriginal land within the Park.

8.3 The Kakadu National Park Board of Management

In 1989 a Board of Management was established for the Park. The functions of the Board are defined by Section 14 (D) of the National Parks and Wildlife Conservation Act 1975. They include:

• in conjunction with the Director, the preparation of Plans of Management;
• the power to make management decisions consistent with the Plan of Management;
• in conjunction with the Director, the monitoring of the management of the Park;
• in conjunction with the Director, the formulation of advice to the Minister about all aspects of future Park development.

The Board has a responsibility equal to that of the Director to manage the Park and advise the Minister concerning Park policy and management. In the event that the Board and the Director cannot agree, the Minister may take steps to resolve the disagreement, ultimately by arbitration (Section 14a, National Parks and Wildlife Conservation Act 1975).
Management considerations

There are 14 people on the current Kakadu National Park Board of Management, including ten adult Aboriginal people nominated by the traditional owners of the Park; the Chief Executive Officer of the ANCA and its Executive Director, in northern Australia; a person employed in the tourism industry in the Northern Territory acceptable to the Aboriginal traditional owners; and a person prominent in nature conservation (see Appendix I).

The Aboriginal owners of the Park have majority representation on the Board and the Chairperson is selected from the Aboriginal members. This arrangement reinforces the status of Aboriginal traditional owners as the landlords (lessors) of much of the Park area.

8.4 Plans of management


A Plan of Management enables management to proceed in an orderly way over a specified period of time by:

- outlining the basis of resource management programs;
- helping to reconcile competing interests;
- identifying priorities for the allocation of available resources;
- facilitating public understanding of and involvement in the planning process;
- providing a basis for future plans.

Toward the end of the life of each Plan the intention to prepare a new Plan is announced. Representations are sought from the general community and special interest groups and public consultation is encouraged to assist in the development of the new Plan.

The *National Parks and Wildlife Conservation Act 1975* specifically requires that due regard is given to the interests of traditional owners (and other Aboriginal people with interests in the Park) in the preparation of Plans of Management.
8.5 Park management principles

A concept fundamental to the management of the Park is that many Park values have been determined partly by the activities of humans over the last 60,000 years. Although it is intended to reverse the undesirable consequences of recent human activity, long-standing traditional land use practices are regarded as integral components of the system. The following are regarded as the overriding principles that govern the management of the Park:

- **Aboriginal rights**: Much of Kakadu National Park is owned by Aboriginal people who have leased their land to the Director of National Parks and Wildlife to be operated as a national park. As freehold landowners the Aboriginal people of Kakadu have rights and expectations, including the right to hunt and forage, which they may wish to exercise from time to time.

- **Natural and cultural heritage**: The conservation of the natural and cultural features of the Park is fundamental to its management.

- **Tourism**: While recognising an obligation to encourage public appreciation and enjoyment of the Park, the provision of access to the Park by visitors must not be at the expense of, or allowed to take priority over, the preceding.

- **Communication of Park values**: The promotion of a continually developing program to communicate Park values to visitors is an integral part of management.

### Key management objectives

With the above principles in mind the following key management objectives were identified in the 1991 Plan of Management:

- to establish a plan of management in which Aboriginal people associated with the Park play a major role;
- to give special protection to Aboriginal art sites, sacred sites and other sites of significance to Aboriginal people;
- to institute an innovative Park management regime conforming to the highest international standards;
- to protect Park resources from the undesirable consequence of fire, erosion, environmental change, pollution, and other activities of people;
Management considerations

- to rehabilitate areas damaged by feral and introduced animals and plants, and recent human impacts;
- to cooperate with neighbours in complementary management programs which help to protect Park resources;
- to develop an inventory of all relevant resources in the Park;
- to stimulate interest in nature conservation and Aboriginal culture by the development and implementation of an imaginative communication program;
- to provide information and guidance to visitors about potential hazards in the Park and ensure their safety as far as possible.

8.6 Park administration

Kakadu National Park is managed on a day-to-day basis by officers of the Commonwealth Government's Australian Nature Conservation Agency. In 1994 the Park had 74 staff of whom approximately one-third were Aboriginal people. These officers share in implementing management programs every day of the year over the entire Park estate of approximately 20,000 km².

Representatives of traditional owners of land in the Park are involved in the recruitment of all staff to ensure that only staff who share a commitment to the concept of joint management are employed. The Park has a strong commitment to staff development and in particular to providing appropriate training programs for Aboriginal people from the region.

Park-wide functions, including administrative, coordination and scientific functions are managed from Park headquarters near the township of Jabiru. The majority of day-to-day field work is managed from six administrative centres strategically located throughout the Park.

Where appropriate, contract arrangements are used to provide support for Park operations, particularly for the provision of specialist advice and maintenance services. Wherever possible local Aboriginal enterprises are encouraged to bid for the supply of contract services.

8.7 Research and monitoring

A considerable amount of scientific and cultural heritage research has been undertaken in Kakadu National Park by external consultants and ANCA staff. ANCA has funded a substantial research and survey effort.
Details of past and current research are contained within the Plans of Management. Research in Kakadu is permitted only after consultation with Aboriginal people and subject to conditions of a current permit. The Kakadu National Park Research Advisory Committee has been established to provide advice to the Director and the Board of Management about research in the Park and to assist with evaluation of research proposals.

8.8 Leases and in-holdings

Township of Jabiru

The Director of National Parks and Wildlife leases 13 km² of the Park estate to the Jabiru Town Development Authority for the development of Jabiru as a regional town centre. Jabiru, with a population of 1300 people, was established as a town to service the regional mining industry. In recent years the town’s tourism functions and facilities have become increasingly important. Development of the town is controlled by provisions of the Plan of Management and a Town Plan. No alterations to the Town Plan can be made without the approval of the Director of National Parks and Wildlife.

Other leases and in-holdings

There are a number of small leases and in-holdings within the Park, most of which predate the declaration of the Park. The Director of National Parks and Wildlife may only issue leases or licences in respect of land in the Park in accordance with the Plan of Management.

8.9 Aboriginal communities within the Park

The lease agreements for Aboriginal Land in the Park contain provisions for Aboriginal people to occupy areas of land in the Park for residential purposes. The Australian Nature Conservation Agency regards it as advantageous that Aboriginal people with traditional responsibilities for the land continue to live in the Park.

Approximately 300 Aboriginal people reside within the Park in both the township of Jabiru and in a number of small communities, often based around extended family groups, that are located throughout the Park. These smaller communities, commonly referred to as outstations, are
typically occupied by Aboriginal people who maintain a traditional relationship with the land they reside on. Support services to these communities are provided by Aboriginal organisations in the region. Proposals for the development of new outstations are subject to the provisions of the Plan of Management.

8.10 Management of natural resources

Landscapes

In very broad terms the major landscapes of the Park may be summarised as including five major topographic regions:

- **The coastal plains**: subject to periodic tidal inundation, vegetated mainly by mangroves and other salt-tolerant plant species with some patchy deciduous rainforest between. These areas are important saltwater crocodile and bird habitats.

- **The freshwater floodplains**: Seasonal wetlands inundated during the wet season. Sedges and paperbark species are the dominant vegetation, and these areas are important habitats for many species of birds, some mammals and reptiles.

- **The lowlands**: mostly gently undulating eroded plains with occasional rocky ridges. Vegetation is dominated by eucalypts in woodlands and open forests, with savanna, grasslands, scrub and pockets of rainforest. The woodlands are important bird and small mammal habitats, and are vital for the survival of some rare species.

- **The Arnhem Land plateau, escarpment and outliers complex**: a wild and strikingly scenic landscape that is ecologically very diverse. These areas provide habitat for a distinctive assemblage of species, many of which are relict or restricted in range.

- **The southern hills and basins**: mostly in the south of the Park, comprise a complex of rugged outcrops and sloping river and creek valleys. Two biogeographic systems of major importance overlap in this region: the monsoonal Torresian system to the north, and the arid Eyrean sub-region to the south. This interface is very significant biologically, providing habitat for rare and endangered species not found elsewhere in the Park.
Geology and soils

The management of geological resources centres on the development of appropriate interpretive material that highlights the evolutionary history of the Kakadu landscape.

Management in the context of soils mainly centres around the need to minimise unnatural erosion of soil, particularly in the relation to roads, tracks and camping areas. The Park is committed to the appropriate management and eventual rehabilitation of gravel pits that are used as sources of road building materials.

Water

Water management programs focus on the impact of the recreational use of water bodies, particularly of small freshwater pools in the stone country, saltwater intrusion into freshwater wetland systems, impact of the use of ground-water resources and public health issues.

Wildlife

Wildlife management programs are based on maintaining natural systems with the aim of sustaining the long-term integrity of individual species and communities. Since the declaration of the Park, significant effort has been directed at developing an inventory of species occurring in the Park and some base-line assessment of the state of wildlife populations. ANCA encourages research directed at improving understanding of ecological processes and interrelationships affecting the state of wildlife in the Park.

Given that much wildlife, especially birds, is highly mobile and that some bird species are migratory, management and research workers try to avoid considering Kakadu in isolation. Populations of wildlife have to be considered in the context of their entire geographic range. It is imperative that plans for the conservation of wildlife in Kakadu are considered in a regional, national and even international context.

It is expected that in the future the management of wildlife resources in Kakadu will focus increasingly on monitoring of the status of populations and communities and the targeted conservation of prioritised problem areas and communities (Russell-Smith & Miles, in press).
Of particular concern is the need to have appropriate management programs in place in respect of endangered and threatened species in the Park.

Many wildlife species are utilised by Aboriginal people through traditional harvesting but impacts of this activity are regarded as negligible.

Anglers also impact on fish populations in the Park, particularly barramundi. Fishing in Kakadu National Park is accepted as a legitimate recreational activity in the Park but careful management of this is required.

Alien species

Significant resources continue to be given to the management of alien species in the Park.

In the first decade of the life of the Park much of this effort was dedicated to the removal of feral water buffalo. As a result of this program there has been significant recovery of plant species that were heavily grazed by buffalo. Saltwater intrusion into freshwater habitats and drainage of freshwater wetlands, often directly linked to large numbers of buffalo grazing in these wetlands, has also been ameliorated.

Park staff continue to be concerned about the impact of alien animal species in the Park with the major problems being caused by animals such as pigs, feral cats and European honey bees. Staff are also concerned about the interaction between domestic dogs and wild dingoes in the Park (impact on the genetic integrity of the dingo population) and possible impacts of the cane toad should populations of this animal become established in the Park.

Weed species are of special concern to both the Australian Nature Conservation Agency and traditional owners of land in the Park. Weeds have the capacity to be highly invasive, often cause substantial change to habitats with subsequent impacts on other wildlife and are usually difficult to control.

The major weed species in Kakadu requiring sustained control effort are the woody shrub *Mimosa pigra*, a floating aquatic fern *Salvinia molesta*, and grass species such as *Brachiaria mutica*, *Adropogon gayanus* and *Pennisetum polystachion* (Russell-Smith & Miles, in press).
Fire management

The annual application of fire is a major influence on the landscapes and wildlife of Kakadu National Park. The active use of fire as a management tool in Kakadu is discussed in detail in chapter 7.

Operations for the recovery of minerals

As part of the Commonwealth Government’s 1978 decision in relation to the future of the Alligator Rivers Region, the boundaries of Kakadu National Park were created specifically to exclude areas of land covering the Koongarra, Jabiluka and Ranger uranium deposits.

To date only the Ranger uranium deposit has been developed with production commencing in 1980. Development of the Koongarra and Jabiluka deposits has not proceeded due to Commonwealth Government policy restricting the number of operating uranium mines in Australia.

The Commonwealth Government has maintained its commitment to ensure that the values of Kakadu National Park are not directly impacted on by mining activity. It maintains its own specialist agency, the Environmental Research Institute of the Supervising Scientist (ERISS), to research potential impacts of mining activity on the Park environment. The results of this research are used in setting management prescriptions for the Ranger uranium mine.

The National Parks and Wildlife Conservation Act 1975 contains special provisions to preclude mineral exploration and mining activity within the Park.

8.11 Management of cultural resources

Sacred sites and sites of significance

A register of Aboriginal sacred sites and sites of significance in Kakadu is maintained by Park staff. Park staff also liaise with the Northern Territory Aboriginal Areas Protection Authority and the Northern Land Council regarding the management of these sites. When requested to do so by custodians of the sites, the boundaries of these sites may be formally described and access restricted under provisions of the Regulations of the National Parks and Wildlife Conservation Act 1975.
Formal description and signposting of these places is regarded as only desirable when it is clear that without these steps there is a high risk of the sites being visited by Park visitors.

**Rock art and archaeological sites**

Kakadu’s rock art heritage represents the world’s longest continuing artistic tradition and is an unparalleled record of the history of a landscape and its human occupation.

The main management objectives in relation to rock art sites are:

- to recognise the interests of site custodians and to consult with them regarding all aspects of site management;
- to preserve the sites;
- to systematically record all sites in the Park and to establish a program for their ongoing management and conservation; and
- to interpret Aboriginal prehistory and rock art to visitors by developing selected sites for visitor viewing and providing information on Aboriginal culture and sites.

The on-going conservation of sites is a major challenge given the number of sites and the range of factors influencing them, eg: water washing over painted surfaces (or transpiring from the rock itself); animals sheltering in art sites; birds and wasps building nests on painted surfaces; vegetation, including roots and lichens, clinging to painted surfaces; termite nests and passages over painted areas; exfoliation of rock surfaces; and disturbance of dust and other deposits caused by animals including humans (Hughes & Watchman 1983). Other adverse agencies include chemical reactions, air pollution, and microbiological growths (I Haskovec, pers comm).

Conservation work focuses on the following activities:

- Site recording using photogrammetry and other documentation techniques (Gillespie 1983): Once sites are located, site recording and survey photography, including photogrammetric recording, takes place to establish a base record from which physical changes can be measured.
- Site protection: This includes installation of silicone drip lines where appropriate to divert water from painted surfaces, removal of wasp nests and the removal of vegetation which presents a threat to painted
surfaces. Where appropriate fences may be constructed to keep visitors and animals such as feral pigs from touching painted surfaces.

- Research into factors contributing to the deterioration of painted surfaces and techniques for the restoration of damaged art.
- Development of infrastructure: Where a decision is taken to open a site for public use it is usual to install appropriate infrastructure to accommodate tourist traffic eg. installation of defined walking tracks, boardwalks, and stone paving to direct visitor traffic and to reduce dust levels.
- Development of appropriate signage and information for tour operators and Park visitors that engenders respect for the art and awareness of its importance and threats to its conservation.
- Supervision of visitors at art sites.

An important initiative in the Park has been the establishment of a rock art management project based on the contract employment of Aboriginal people to carry out site recording and maintenance work.

Other archaeological sites in Kakadu include occupation sites (some of which are very large), shell middens, stone arrangements, beeswax motifs, and petroglyphs. These sites are systematically recorded and where necessary a site specific conservation strategy is implemented.

**Historic sites**

There are a number of historic sites in the Park that reflect recent Aboriginal and non-Aboriginal history. Many of these sites relate to activities associated with early mining activity, pastoralism, buffalo harvesting, timber cutting and safari-based tourism. Given the extremity of local conditions (climate, termite attack and fire) many of these sites are significantly damaged or mere remnants of past activity. A priority is given to the documentation and recording of these sites. Where appropriate, advice is sought on the regional significance of historic sites upon which decisions regarding priorities for conservation action are based. A conservation plan for the site may also be developed which then provides the basis for conservation intervention.

**Oral cultural heritage**

Oral cultural heritage is a particularly vulnerable resource, especially in the context of Aboriginal life history and tradition.
A priority is being given to oral heritage projects in the Park such as the recording of Aboriginal languages and place names and Aboriginal and non-Aboriginal life histories.

Of particular importance to the Park is the recording of Aboriginal traditions and knowledge in the context of Aboriginal management of the Kakadu landscape. Much of this information is invaluable to current generations of land managers in the Park.

8.12 Visitor use

Overview
Kakadu experienced significant growth in visitor numbers over the period 1982–1990 (see Table 8.1).

During the period 1990–1992 economic conditions led to a downturn in the number of domestic (Australian) visitors to the Northern Territory and this has been reflected in a slight downturn in visitors to the Park during that period. With improved economic conditions the Park is experiencing renewed growth in visitor numbers.

It is expected that visitor growth to the Top End, and hence Kakadu, will grow in the foreseeable future as a direct result of energetic tourism promotion campaigns by both the Northern Territory Tourist Commission and the private sector (Northern Territory Tourist Commission 1994).

Particular emphasis is also being placed on attracting overseas visitors to Australia and it is expected that Kakadu's share of this market will also grow.

The above industry trends, coupled with increased interest in nature-based tourism and the recognition of World Heritage sites as prime tourism destinations, suggest that a major challenge for the Park over the next decade will be the appropriate management of increasing visitor use.

Aboriginal attitudes towards Park visitors
Tourism – the notion of travelling long distances to see someone else's country as a form of recreation – did not exist in Aboriginal society. However, travelling in search of jobs, education, relatives and friends,
and ‘learning by seeing’ are now important aspects of modern Aboriginal society.

Aboriginal people understand other people’s desire to see their lands and to appreciate and value the Park’s attractions. The traditional owners’ preference is that visitors come to Kakadu to appreciate the heritage values of the Park and its significance to Aboriginal people.

They hope that visitors will appreciate the importance of Kakadu as the homeland of its traditional owners and that visitors can respect the need of traditional owners to restrict access to some areas of the Park.

Traditional owners also have a strong commercial interest in tourism through their ownership of commercial accommodation houses and tours in the Park.

Visitors to Kakadu

The Australian Nature Conservation Agency places a priority on monitoring patterns of visitor use of the Park. Since the Park’s declaration, a number of visitor surveys have been commissioned and the information relating to visitors to Kakadu summarised below is largely based on the results of this survey work (Gale 1984; Preece 1989; Knapman 1990; Environment Science & Services 1994a).

Visitor numbers

The growth in visitor numbers to Kakadu National Park is shown in Table 8.1.

Table 8.1 Visitors to Kakadu National Park, 1982–93 (ANCA data)

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<td>Visitors (‘000)</td>
<td>45.8</td>
<td>57.8</td>
<td>75.2</td>
<td>101.6</td>
<td>131.0</td>
<td>195.0</td>
<td>220.0</td>
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<td>238.0</td>
<td>210.0</td>
<td>205.0</td>
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As well as using visitor numbers as an index of visitor use, it is important to consider length of stay or ‘visitor days’ as another measure of the significance of visitor use of the Park.

Visitors tend to stay an average length of 3–4 nights in the Park though this fluctuates seasonally; the average length of stay reduces to around
two nights during the wet season (Nov–April). Private visitors tend to stay longer than those on commercial tours.

A small proportion of total visitors (probably less than 10%) visit Kakadu on day trips from Darwin. Some members of the local tourism industry have expressed concern that promotion of day visits to the Park is not in the Park's best interests given that the distances travelled and resulting short length of time in the Park can lead to visitors' dissatisfaction with their visit to Kakadu.

Seasonality

Visitation to Kakadu National Park, as with other destinations in the tropical north of Australia, is highly seasonal. About 80% of all visitors use the Park between May and October (the dry season). Fifty per cent of all visitors use the Park during June, July and August with 20% of all visitors arriving during the month of July.

If the current seasonal trends continue in tandem with expected visitor numbers then a number of management problems associated with peak periods, such as the need to design infrastructure for peak loadings and perceptions of overcrowding at some sites at peak times, will need to be addressed. It may also be necessary to require scheduling of visitor use (eg through coach timetables) and otherwise regulate visitor numbers at some sites to ease a sense of overcrowding and reduce local impacts of visitor use.

Visitor profile

A feature of visitor use of the Park is that the vast majority of visitors are on their first trip to the Park. As a consequence their visit is often 'a journey of discovery' and visitors arrive 'without knowledge or experience of the Park' (Environment Science & Services 1994a).

Visitor surveys during the 1980s found that most visitors to the Park (80–85%) were domestic visitors from other places in Australia. The proportion of overseas visitors to Kakadu is increasing though and the proportional representation of these visitors differs according to the time of year; surveys in April 1993 found that 64% of visitors were from overseas while in July 1993 the proportion was much less at 28% (Environment Science & Services 1994a).
In recent years there has also been a trend towards more visitors coming to the Park on commercial tours. Surveys during the early 1980s (Preece 1989) found that only 17% of visitors came to the Park on organised tours while surveys in 1993 found that around half of the visitors surveyed came to Kakadu on tours.

Reasons for visits and visitor satisfaction

It would appear that since the Park's declaration there has been a gradual change in the reasons for visiting Kakadu National Park with increased interest in wildlife viewing and visiting rock art sites and a consequent decrease in the relative importance of other recreational activities such as fishing.

In a 1990 survey (Knapman 1990) it was found that both international and domestic visitors rated wildlife viewing and visiting rock art sites as providing the greatest satisfaction followed by bushwalking, camping and scenic driving/tours.

In general this survey found that visitor satisfaction levels with the Park were very high. Of interest were particularly high satisfaction levels recorded for talks, guided walks and assistance provided by Park rangers. Apart from complaints regarding nuisances such as insects, heat and dust, the major complaints from visitors were the high costs and/or quality of accommodation, the conditions of roads, and congestion and noise at some sites.

More detailed survey work in 1993 (Environment Science & Services 1994a) also found that the vast majority of visitors were satisfied with their visit to the Park. These visitors rated the opportunity to appreciate the scenery, to view wildlife and rock art and to learn about the ecological and cultural heritage of the Park as major reasons for wanting to visit. This survey also found high levels of satisfaction with Park staff and tour guides.

The 1993 survey also found that the World Heritage status of the Park was a factor that attracted many visitors and that a significant majority of visitors came to Kakadu seeking a wilderness experience.
PLATE 8.1 Aboriginal people continue to hunt in Kakadu National Park, particularly on resource-rich floodplains. Here two women with hunting sticks are searching for galawarn, or sand goannas (Diane Lucas).

PLATE 8.2 The Gagudju Crocodile Hotel (Gagudju Association).
PLATE 8.3 Bowali Visitor Centre, Kakadu National Park (John Gollings).

PLATE 8.4 Bowali Visitor Centre display (John Gollings).
PLATE 8.5 Visitors at the Anbangbang Gallery (ANCA).

PLATE 8.6 Rock art conservation (Ivan Haskovec).
PLATE 8.7 Commercial tour operators training in Kakadu National Park (Greg Miles/ANCA).

PLATE 8.8 Park rangers at work on the waterways of Kakadu (Greg Miles/ANCA).
PLATE 8.9 Infestation of waterways by the water weed Salvinia molesta (Michael Storrs).

PLATE 8.10 Biological control of Salvinia molesta (Michael Storrs).
8.13 Managing visitor use

Park management aims:
- to provide a range of appropriate recreational activities in Kakadu whilst providing for protection and appreciation of cultural and natural assets;
- to provide reasonable access and facilities for recreational activities undertaken in different landscapes; and
- to ensure that recreational activities do not adversely affect Aboriginal interests.

It is imperative that visitor use of the Park is planned and organised and not allowed to develop incrementally in a uncontrolled and overly market-driven fashion.

A number of planning tools, including the use of zoning, Park-wide management strategies and site-specific area plans, are used to assist in the orderly development and management of visitor use of the Park.

Zoning

Zoning in the Park defines the kinds of activities to be allowed within each designated area, as well as placing an upper limit on the kinds of utilisation of each area. For these purposes the Park has been divided into four primary management zones:

**Intensive Management Zones:** These zones provide for maximum recreation and management infrastructure development, and include all main roads in the Park. The areas include some principle accommodation areas including major (developed) camping grounds and Park administrative facilities.

**Intermediate Management Zones:** These zones allow for infrastructure development (though not hotel/motel developments) as long as they do not intrude significantly into the landscape. Aboriginal outstations may be established in these zones.

**Minimum Management Zones:** These are generally remote, extensive areas where priority is given to conservation values. Access is allowed on developed four-wheel drive tracks. Park management is generally limited to erosion control, feral animal control, fencing of sensitive or
Management considerations

damaged areas, approved research and limited signposting. Bushwalking and bush style camping is allowed subject to issue of permits. In some of these areas limits are placed on the numbers of visitors allowed into the area at any one time.

Wilderness Zones: Reservation of these areas is designed to protect examples of land system types in the Park, and to provide for long-term research and conservation. No permanent facilities are provided in such areas except for access for rehabilitation or research purposes. Uses appropriate to these areas are bushwalking and non-manipulative scientific research.

Under the provisions of the current Plan of Management (1991) there is also a scientific research zone. This zone encompasses the Kapalga Research Station. This area has been set aside for the development and maintenance of approved scientific research or educational programs related to wildlife management. Designation of Kapalga as a scientific research zone has not precluded non-manipulative scientific research in other zones.

Area management plans

In 1993 the Australian Nature Conservation Agency commenced a process of developing area management plans for specific visitor sites in the Park.

The area plans are intended to provide a concise statement of the role or purpose of a site in the Park and strategies for achieving that purpose. They are based on recognising the natural, cultural and recreational values of a site, and defining desired ends and prescribing strategies to protect the sites values (Environment Science & Services 1994b).

The plans are developed in consultation with traditional owners and the tourism industry and the planning process includes opportunity for public comment on draft plans.

Accommodation

The development of accommodation in the Park is permitted in accordance with prescriptions outlined in the Park’s Plan of Management.

Given the long-term nature and on-going management implications inherent with the development of most styles of accommodation, it is important that all proposals for the development of new accommodation
are carefully considered. Important considerations include the benefit for the Park that will result from the development, long-term management implications and whether the development is necessary.

Commercial motel-style accommodation is available in the Park at Cooinda, Jabiru and adjacent to the South Alligator River on the Arnhem Highway. Lodge-style accommodation is available in Jabiru at the Kakadu Frontier Lodge, and similar modestly priced accommodation is available at Gagudju Lodge Cooinda and the Kakadu Holiday Village. The Youth Hostels Association of the Northern Territory has limited accommodation near the Border Store.

In recent years there has been increased interest in the establishment of semi-permanent safari style tent accommodation and opportunities have been made available for these to be developed in existing camping areas in the Park. These developments are managed in accordance with a Park-wide safari camp strategy.

Park staff care for 25 designated camping areas in the Park ranging from those with sealed access, ablution facilities and water supplies to bush-style camping areas with no facilities and unformed road access. Bush-style camping is also available outside of designated camping areas and this activity is regulated through a permit system.

**Access**

The vast majority (about 98%) of visitors arrive at the Park by road. Major arterial roads are maintained by the Northern Territory government but the remainder of the substantial road and track network in Kakadu is maintained from Park operations funds.

Many of these roads are unsealed and require regular maintenance to maintain them at acceptable levels. All roads are subject to climatic extremes of water saturation and flooding each wet season. These two factors mean road maintenance is an expensive and time consuming Park management function.

A small number of people reach the Park by air with airstrips at the Ranger uranium mine site and Cooinda providing the main points of entry and exit for visitors. A number of other smaller airstrips are located in the Park and used irregularly for wet season and emergency access.
Airspace over Kakadu is used regularly by visitors taking scenic flights, especially over the spectacular escarpment country in the Park. Scenic flights over the Park are very popular but can also present a number of management problems due to noise and effect on other Park users and residents. To address this issue a Fly Neighbourly Agreement (FNA) has been negotiated with airspace users. The FNA asks pilots to follow a code of practice that includes limiting flights over wilderness areas in the Park to above 5500 feet above ground level (agl) and those over the remainder of the Park to above 2500 feet agl. A number of recognised scenic routes are also identified where the minimum height reduces to 1000 feet agl and the agreement identifies a number of noise sensitive locations in the Park (eg visitor sites and residential areas) over which pilots are asked to maintain a minimum of 3 km horizontal separation. Helicopter landings are only permitted in the Park (outside of licensed airstrips) for management related purposes.

Although access to the Park by water is limited, there is extensive use of major tributaries and billabongs for both wildlife viewing and fishing. Boat launching ramps have been developed on the East and South Alligator Rivers as well as at a number of popular billabongs. The use of non-motorised craft on major waterways is not encouraged because of the presence of large estuarine crocodiles. Commercial boat tours are limited to certain waterways and the style of operations permitted in given areas of the Park is defined in a Park-wide boating strategy. Management issues relating to boating include the quality of information presented on tours, public safety, interference with wildlife and bank erosion.

8.14 Commercial activities

The National Parks and Wildlife Regulations allow the Director of National Parks and Wildlife to approve, with conditions, the operation of commercial activities in Kakadu National Park. The Director may also withdraw permission for commercial operations which do not meet specified conditions.

Commercial activities are now commonplace in national parks and reserves throughout Australia and overseas. Properly regulated commercial activities can enhance the experience for visitors as well as promote the values of national parks and enhance management goals.
In Kakadu the licensing of commercial activities is a particularly important tool in managing all commercial activities, especially commercial tour services.

In June 1993, 175 companies, 22% of which are based in the Northern Territory, were licensed to carry out commercial tours in the Park. These tour companies mostly comprised a number of coach companies that conduct a small number of tours to the Park each year, coach companies conducting regular services to the Park and numerous smaller adventure tour operators. Other tour operators specialise in providing specialist charter services, high quality nature-based tours, commercial fishing safaris and aerial tours.

Permits to conduct commercial activities are usually issued for a period of 12 months, though they may be granted for longer periods (though generally not longer than the life of a Plan of Management) in the case of certain capital intensive operations. A competitive tender system, including consideration of past performance, is used when necessary to differentiate between different companies vying for limited opportunities in the Park. Permits may be withdrawn if the operator does not fulfil permit conditions.

Accreditation of tour operators in the Park, which has both traditional owner and industry support, is expected to be developed in the future with expanded education and training programs for tour operators. A Kakadu National Park Tourism Consultative Committee was established in 1990 to co-ordinate and liaise with operators and the tourism industry. This body includes representatives from the Australian Nature Conservation Agency, industry based tourism groups from the regional centres of Darwin, Katherine and Jabiru, the NT Fishing Tour Operators Association and the Northern Territory Tourist Commission. Kakadu staff have also produced a tour operators handbook in conjunction with traditional owners, the Northern Land Council and the Darwin Region Tourism Association.

Aboriginal enterprises

Involvement by Aboriginal traditional owners in economic/commercial activities in the Park has steadily increased since the Park's declaration. As well as owning tourist accommodation the Gagudju Association also
has exclusive rights to run commercial boat tours at Yellow Water in the centre of the Park.

The Djabulukgu Association is also developing commercial opportunities in the Park including the operation of a boat tour and retail outlets at the Bowali Visitor Centre at Park headquarters.

Proposals from traditional owners in the Park for further commercial activities will be assessed by the Park’s Board of Management taking into account the level of control held in the operations by Aboriginal interests, benefit to the Park and the extent to which they enhance traditional owners’ interests.

Commercial filming

Permits have been required for commercial filming and photography in Kakadu National Park since 1989. Approvals are generally only given for activities that reflect the cultural and conservation values of the Park and limits may be imposed on the numbers of such activities that may be allowed. Photography of Aboriginal people, sensitive sites and Aboriginal living areas is not permitted except as approved by and in consultation with Aboriginal organisations and the Park Manager. The above requirements regarding commercial filming in the Park do not apply to the gathering of ‘news of the day’.

Other commercial activities

From time to time the Park Management is approached with proposals for other forms of commercial activity. The Board of Management may consider such proposals on a case-by-case basis and they may only be approved if they meet Park management objectives and not in conflict with the Plan of Management.

8.15 Communication of Park values

Visitors require information to help them plan their visit to the Park, to orientate themselves to facilities and services available, to inform them of hazards in the Park and to enhance their understanding of the Park’s values. Programs to provide these services are managed in the context of a communication plan for the Park. This plan aims to identify target audiences, the main messages that need to be communicated and the
appropriate mediums for this, be cost effective and provide for the regular evaluation of material that is produced.

The very popular Bowali Visitor Information Centre at Park headquarters is an important facility where an international standard display and orientation information are available for Park visitors.

The Warradjan Aboriginal Cultural Centre near Cooinda was opened in 1995 as a place where Aboriginal people present their culture and history to Park visitors.

Interpretive programs include a highly successful annual (dry season) program of walks and talks in the Park (over 100 activities per week), annual production of a popular colour visitor guide that includes sample itineraries for visits to the Park, a comprehensive series of 'Park notes' relating to specific sites and Park related issues, a Schools Kit and education guide to the Park and a tour operators handbook. Numerous orientation and information signs are located throughout the Park at popular visitor sites.

In the development of all educational and interpretive material a priority is given to incorporating an Aboriginal cultural perspective, including the use of Aboriginal place names. Attention is also given to having information material produced in languages other than English to reflect the growing numbers of non English speaking visitors to the Park.

8.16 Public safety and enforcement of Park regulations

Rangers and wardens at Kakadu National Park are appointed pursuant to the National Parks and Wildlife Conservation Act 1975 and exercise the powers and functions conferred on them by the Act and Regulations. Under Section 38 of the Act any member of the Commonwealth or Northern Territory Police Force is an ex-officio warden.

Northern Territory authorities co-operate in relation to such matters as the protection of sacred sites, control of liquor sales in the Park and are responsible for police matters. The Northern Land Council also has legislative responsibilities over matters such as sacred sites, as well as other requirements under the Land Rights Act.

Safety is a major concern for staff at the Park and Aboriginal traditional owners. Staff training in safety and first aid is a Park priority and Park
staff provide a high level of support to the NT Police in search and rescue operations. A priority is also given to alerting all visitors to hazards in the Park which include becoming lost, dehydration, exposure to insect borne diseases, threats from wild animals (particularly crocodiles) and hazards associated with the use of roads in the Park.

References


Conclusion

Tony Press and David Lea

The establishment of Kakadu National Park and its joint management arrangements are a significant episode in the history of Australia. In the year that this book was published Kakadu was sixteen years old and work had begun on the fourth Plan of Management for the Park. This Plan will see the Park through into the 21st century.

In early 1995 the long, complicated and intense program of public consultation seeking input into the new plan began. The major issues that dominate all Park planning processes will be raised, debated and explored. These issues will include tourism and development, priorities for conservation, allocation of resources to Park management programs, access, and commercial regulation.

Park management: How does joint management work? Is it successful? Are the rights and wishes of the Aboriginal traditional owners reflected properly in the plan? How can management performance best be assessed? How successful is the fire management program? How can fire management be improved? Are weeds and feral animals being managed properly? Do new facilities need to be constructed? How can a balance be forged
between protecting and enhancing Aboriginal interests, tourism, conservation and preservation, environmental protection, education and research? Are Park resources allocated wisely?

The Board of Management has determined that the Aboriginal Consultative Committee will be given special resources to ensure that they have maximum input into the new Plan. The future success of these joint management arrangements will be significantly influenced by the strength of Aboriginal involvement in the planning and management of the Park.

Tourism: How does Kakadu fit in the national and regional economy? Will increasing visitation 'foul the nest'? What sort of information do visitors want? Will it be necessary to limit visitors numbers to the Park in general or at certain sites? What is a reasonable fee structure? What sort of special provisions are needed for the physically handicapped, the aged and overseas visitors? Has overambitious or misleading marketing led visitors to have false expectations? Are certain visitor activities inappropriate in Kakadu?

Accommodation: Is the accommodation in the Park appropriate? Is there a balance between hotel/motels, hostel, camping and lodge style accommodation? Is there a place for cheaper accommodation? Is the safari camp strategy working? Should any camping areas be closed? Should new ones be opened? What sort of private developments should be allowed in the Park?

Jabiru: What is the future of Jabiru? What special conditions should apply to Jabiru town residents (eg pets and plants introduction)? Does the lease with the Jabiru Town Development Authority need to be renegotiated? Is there a need to develop a better relationship between the town and the Park? How do the disposal of waste and use of fertilisers in the town affect the Park?

Commercial activities: How will Ranger Uranium Mine affect the Park? What sort of regulation is needed for commercial operators? Should permits be valid for one year, five years or for variable periods? Should there be compulsory accreditation for
commercial operators in the Park? How should breaches of regulations or permit conditions be handled?

Access: Should all roads be all-weather roads suitable for conventional vehicles? Is it a good thing to rest sensitive sites (such as Jim Jim Falls) during the wet season by closing them to four-wheel drive vehicles? Is the prohibition on access by helicopters necessary? Should commercial self-drive boats be available?

Activities such as bushwalking, fishing, and bird watching: Should remote area bushwalking be unrestricted? How can vandalism and removal of artefacts from sites be controlled? Should bushwalking routes be one-way to prevent overlapping? Should the return notification system be improved and made compulsory? Should bushwalkers and others going into remote areas carry emergency locational devices? Who should pay for the cost of search and rescue? Should fish caught in the Park be taken out of the Park? Are present bag limits reasonable?

The editors and authors of this book, all non-Aboriginal, have made a serious attempt to understand the views of the Aboriginal traditional owners, their history and their way of seeing, interpreting and understanding Kakadu as culture, nature and life. However, we have used the language and methods of western science to classify, describe and understand the plant and animal kingdoms and to describe and understand past events and features of the landscape and the way they interact with each other.

There is no doubt that the Aboriginal traditional owners of the Park have their own cosmology with rigorous ways of interpreting the world (some people have described this rather inadequately as 'ethnoscience' or 'folk science'). We hope that future editions of this book will contain chapters written by the Aboriginal traditional owners of Kakadu, presenting their world view to the people of the world.

Kakadu is and always will be an important Australian place. As well as the continuing struggle to conserve a beautiful and unique environment, the controversies over uranium and gold mining, the fight for Aboriginal land rights, the disputes over World Heritage listing, the
Tony Press and David Lea

Northern Territory's assertions of control and its quest for statehood, all serve to keep Kakadu in the national and public eye.†

We should always remember, though, that for the Aboriginal traditional owners Kakadu is not an exotic destination in remote Australia: it is their place, the land of their forebears and the future for their children.

† This story is told in some detail in Lawrence D, Forthcoming. Kakadu: the making of a National Park, NARU and ANCA.
Appendix I

Kakadu National Park Board of Management

Members appointed to October 1999:

1. Members nominated by the traditional Aboriginal owners of Kakadu National Park:
   
   Brian Baruwei (Chair)
   Yvonne Margarulu (Deputy Chair)
   Sandy Barraway
   Peter Jatbula
   Mick Alderson
   Jessie Alderson
   Jacob Nayinggul
   Jonathon Nadji
   Victor Cooper
   (one position currently vacant)

2. A person employed in the tourism industry in the Northern Territory acceptable to the traditional Aboriginal owners of Kakadu National Park:

   Mr Chris Burchett

3. A person prominent in nature conservation acceptable to the traditional Aboriginal owners of Kakadu National Park:

   Dr Richard (Dick) Braithwaite

4. The Director of National Parks and Wildlife

   Dr Peter Bridgewater

5. Executive Director, Directorate for Biocultural Landscapes (North), Australian Nature Conservation Agency:

   Dr Anthony (Tony) Press
Appendix II

Kakadu National Park Plan of Management Consultative Committee, 1995

Nourlangie†
Yvonne Margarulu, Valerie Balmoore

Patonga Airstrip†
Rodney Nelson, Eileen Cahill, Colin Moore, Doreen Waldock

Spring Peak†
Eva Petterson

Jim Jim†
Violent Alderson, Mick Alderson, Nellie Bayne

Golondjorr†
Peter Sullivan, Patrick Naguwali, Fred Naguwali

Manukala†
Susan Ilgirr, Bluey Ilgirr

Madjinbardi†
Jimmy WokWok, David Alangale, Shirley Abakari, David Cameron,
Minnie Brennan, Gladys Brennan, Kevin Buliwana, Tony Gamarrawu

Manaburduma†
Paddy Brown, Joshua Bangarr, Neville Narmanjilk, Peter
Djandjomerr, Joseph Bishop, Ruth Djandjomerr, Lennie Barranbar

Kurrajong†
Douglas Hunter

Cannon Hill†
Joseph Manyinbulane

Gunbalanya community†
Jacob Nayinggul, Irene Nayinggul, Doris Nayinggul, Peggy Balmana,
James Wauchope

Limilngan Community†
Lena Henry, Victor Cooper, Sampson Henry

Jawoyn Community†
Robert Lee, Peter Jatbula, Micky Markham

† Outstation communities in Kakadu National Park.
Appendix III

Authors and editors of this publication

A Andersen
Principle Research Scientist
CSIRO Division of Wildlife & Ecology, PMB 44, Winnellie, NT 0821

Alan's main research interests are community ecology (particularly of ants) and the use of bioindicators in environmental monitoring and assessment. He has been associated with Kakadu for ten years, conducting research on ant community ecology, fire ecology, and the use of ants as indicators of ecosystem restoration following disturbance. He is a member of the Kakadu Research Advisory Committee.

John Brock
Vegetation consultant
PO Box 38543, Winnellie, NT 0821

John is the author of the well-known and informative book, *Top End Native Plants*, and has been involved with research and survey work on Top End flora since he first moved to Darwin in 1978. He worked for the Conservation Commission of the Northern Territory for 12 years, and more recently as a vegetation consultant. Much of the material, survey work and research sites for the *Atlas of the Vascular Rainforest Plants of the Northern Territory* (Flora of Australia Supplementary Series 3, ABRS, 1994) written jointly with Liddle, Russell-Smith, Leach and Connors, were in and around the Kakadu area. The Atlas is a follow-up from the more comprehensive Monsoon Rainforest Survey in the NT which was completed in 1991 by Jeremy Russell-Smith.

S Brockwell
Anthropology Student
Department of Anthropology
Northern Territory University
Darwin, NT 0909

Sally first went to Kakadu National Park with the Australian National University archaeological consultancy in 1981. She subsequently conducted research on wetlands sites on the South Alligator River as part of her Master of Arts degree at ANU, and has maintained her interests in Kakadu ever since.

P Forrest
Heritage Consultant
GPO Box 88
Darwin, NT 0801

Freelance writer, broadcaster and consultant. In 1978 Peter was a foundation member of the Kakadu Society which was then advocating creation of the Park. Subsequently he has undertaken several studies of cultural heritage resources within the Park area, and has been actively involved with historical research in the region generally.
Appendix III: Authors & Editors

A Graham
Wildlife ecologist, author and naturalist
currently working in Ethiopia

Born in east Africa, Alistair has spent most of his life living and working in Africa. He is a renowned wildlife manager and the author of two outstanding books about Africa, *The Gardeners of Eden* (1973) and *Eyelids of the Morning* (with P Beard, 1973). In recent years he has worked in Australia and Papua New Guinea as well as Africa, including two stints with ANCA. He was the ANCA planning officer responsible for the 1991 Plan of Management for Kakadu National Park.

DR Lawrence
Project Manager
*Great Barrier Reef Marine Park Authority*
GPO Box 791
Canberra, ACT 2601

A social scientist, David is currently completing a book on the social and political history of Kakadu National Park and the joint management arrangements between ANCA and the Aboriginal traditional owners. From 1993–95 he was a Research Fellow based at NARU, and is now with GBRMPA in Canberra. David has undertaken research on traditional exchange systems and material culture in Torres Strait and Papua New Guinea, and has also worked on a variety of environmental management and development projects.

DAM Lea
Former Executive Director
NARU
PO Box 1458
Armidale, NSW 2350

David retired from the position of Executive Director, NARU, in mid 1994, and is now Emeritus Professor of the University of New England and an Associate of NARU. An academic, he first visited Kakadu in 1991, and served on the Kakadu Scientific Advisory Committee for three years.

RI Levitus
Departmental Visitor
*Department of Archaeology & Anthropology, The Faculties*
*The Australian National University*
Canberra, ACT 0200

Robert began research in Kakadu in 1981 on social history for ANPWS and the Project to Monitor the Social Impact of Uranium Mining. Since then he has continued pure and applied research into the history, culture and politics of Kakadu and neighbouring areas, most recently on the southern section of the Park around Coronation Hill.

RS Needham
Assistant Secretary
*Office of the Supervising Scientist*
40 Blackall Street
Barton, ACT 2600

Stewart led the Bureau of Mineral Resources (now Australian Geological Survey Organisation) mapping team which produced geological reports and maps of Kakadu and the surrounding region between 1971 and 1984. He conducted mineral resource assessments in the Park, designed the South Alligator Conservation Zone, and worked on Coronation Hill. More recently, he has produced geological guides to some of Kakadu’s walking trails. He now heads the Office of the Supervising Scientist, which assesses the environmental impacts of uranium mining and exploration in the Alligator Rivers Region.
Appendix III: Authors & editors

AJ Press
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Casuarina, NT 0811

P Wellings
Park Manager
Kakadu National Park
PO Box 71
Jabiru, NT 0886

Ecologist and bureaucrat, who first came to Kakadu in 1984. After working in the Park for 6 years, Tony moved to Darwin to take up a senior executive position in ANCA. He has been closely associated with the management of Kakadu National Park and other national parks in north Australia.

Ecologist and reluctant bureaucrat. Jeremy’s involvement with the Kakadu landscape and people commenced in 1981, as a naive and enthusiastic PhD student. Since that time he has had the good fortune to work in and around the Kakadu region on many occasions, most recently as an employee of the Park from 1991 until the present, running environmental management programs. Kakadu continues to be a source of wonder and inspiration to both Jeremy and his family.

Ann came to Darwin (and Australia) in 1987, and has worked at NARU on numerous research projects since then. In recent years she has concentrated on the editing and production of NARU publications. Her involvement with this project began in 1993 when ANCA invited NARU to take over the editing and production of the Kakadu book. Two years and much hard work later she feels as though she knows the text (and some of the editors and authors) inside out! However, she wouldn’t have missed the experience for the world and through it her respect for Kakadu’s natural and cultural heritage has become even greater.

Peter has worked in Kakadu National Park since June 1980. He first joined the Kakadu team as a base grade ranger and spent most of his years as a ranger working in the Nourlangie and Jim Jim areas of the Park. In 1989 Peter was appointed to the position of Park Manager and became responsible for the day-to-day management of Kakadu National Park. Peter has a strong personal commitment to the concept of joint management with Aboriginal traditional owners and has overseen the management of the Park during a period of rapid change.
Appendix IV

A checklist of the birds in Kakadu National Park

About 280 species of birds have been recorded in Kakadu National Park. This represents over one-third of the total known birds in Australia. The majority are breeding species but there are, in addition, approximately 80 non-breeding migrants from the northern hemisphere and Australia’s southern States.

An attempt has been made to indicate the seasonality, habitat and frequency of the listed birds. The habitats have been contracted and simplified. For example, the escarpment category includes all the varying vegetational and morphological patterns found in that area. Similarly, the abundance of birds in each habitat, indicated by the asterisks, is shown only for the main areas in which they occur.

The checklist was originally compiled by Lindsay Barnett, District Supervisor of Kakadu National Park. It was updated for the purposes of this publication in 1995 by Dr John Woinarski of the Conservation Commission of the Northern Territory. Order, taxonomic nomenclature and common names follow Christidis L and Boles WE, The Taxonomy and Species of Birds of Australia and its Territories, Monograph 2, Royal Australasian Ornithologists Union, Melbourne (1994). The names in brackets are commonly used in tropical Australia.

Because this checklist is continually revised, your reports of birds not listed are welcomed. Please forward details to The Park Manager, Kakadu National Park, PO Box 71, Jabiru NT 0886, phone (089) 381100.
### A checklist of the birds in Kakadu National Park

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<th>Key to symbols</th>
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| Emus           | Dromaius novaehollandiae | All year | **       |            |               |                               |              |                     |

| Mound-builders |                    |          |          |            |               |                               |              |                     |
| Orange-footed scrubfowl | Megapodius reinwardt | All year |           | ***        | *              |                               |              |                     |

| Quails         |                    |          |          |            |               |                               |              |                     |
| Stubble quail  | Coturnix pectoralis | Dry      |           | ***        | *              |                               |              |                     |
| Brown quail    | Coturnix ypsilophora| All year |           | ***        | *              | ***                          | **           |                     |
| King quail     | Coturnix chinensis | All year |           | *          | ***            |                               |              |                     |

| Geese, swans & ducks |                    |          |          |            |               |                               |              |                     |
| Magpie goose     | Anseranas semipalmata| All year |           | ***        | ***            |                               |              |                     |
| Wandering whistling-duck | Dendrocygna arcuata | All year |           | ***        | ***            |                               |              |                     |
| (whistling tree-duck) |            |          |          |            |               |                               |              |                     |
| Plumed whistling-duck | Dendrocygna eytoni | All year |           | ***        | ***            |                               |              |                     |
| (plumed tree-duck) |                    |          |          |            |               |                               |              |                     |
| Freckled duck    | Stictotena naevosa  | Dry      |           |            | *              |                               |              |                     |
| Black swan       | Cygnus atratus      | Dry      |           |            | *              |                               |              |                     |
| Radjah shelduck (burdekin duck) | Tadorna radjah | All year |           | **        | ***            | ***                          |              |                     |
| Green pygmy-goose | Nettapus pulchellus | All year |           | ***        | **             |                               |              |                     |
| Pacific black duck (black duck) | Anas superciliosa | All year |           |            | ***            | ***                          | *            |                     |
| Grey teal        | Anas gracilis       | All year |           | *          | ***            | ***                          |              |                     |
| Garganey         | Anas querquedula   | Dry      |           |            | *              |                               |              |                     |
| Pink-eared duck  | Malacorhynchus membranaceus | All year |           | **        | *              |                               |              |                     |
| Hardhead (white-eyed duck) | Aythya australis | All year |           |            | *              |                               |              |                     |

<p>| Grebes          |                    |          |          |            |               |                               |              |                     |
| Australasian grebe (little grebe) | Tachybaptus novaehollandiae | All year |           | **        | *              |                               |              |                     |
| Hoary-headed grebe | Poliocephalus poliocephalus | Dry    |           |            | **            | **                            |              |                     |</p>
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**Gannets & boobies**

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<tr>
<td>Brown booby</td>
<td><em>Sula leucogaster</em></td>
<td>All year</td>
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**Darters**

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<tr>
<td>Darter</td>
<td><em>Anhinga melanogaster</em></td>
<td>All year</td>
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**Cormorants**

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<tr>
<td>Little pied cormorant</td>
<td><em>Phalacrocorax melanoleucus</em></td>
<td>All year</td>
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<tr>
<td>Pied cormorant</td>
<td><em>Phalacrocorax varius</em></td>
<td>Dry</td>
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<tr>
<td>Little black cormorant</td>
<td><em>Phalacrocorax sulcirostris</em></td>
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<tr>
<td>Great cormorant (black cormorant)</td>
<td><em>Phalacrocorax carbo</em></td>
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**Pelicans**

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<tbody>
<tr>
<td>Australian pelican</td>
<td><em>Pelecanus conspicillatus</em></td>
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**Frigatebirds**

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<tr>
<td>Great frigatebird</td>
<td><em>Fregata minor</em></td>
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<tr>
<td>Lesser frigatebird</td>
<td><em>Fregata ariel</em></td>
<td>All year</td>
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**Herons, egrets & bitterns**

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<tbody>
<tr>
<td>White-faced heron</td>
<td><em>Egretta novaehollandiae</em></td>
<td>All year</td>
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<tr>
<td>Little egret</td>
<td><em>Egretta garzetta</em></td>
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<tr>
<td>Eastern reef egret (reef heron)</td>
<td><em>Egretta sacra</em></td>
<td>All year</td>
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<tr>
<td>White-necked heron (Pacific heron)</td>
<td><em>Ardea pacifica</em></td>
<td>All year</td>
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<tr>
<td>Great-billed heron</td>
<td><em>Ardea sumatrana</em></td>
<td>All year</td>
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<tr>
<td>Pied heron</td>
<td><em>Ardea picata</em></td>
<td>All year</td>
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<tr>
<td>Great egret (large egret)</td>
<td><em>Ardea alba</em></td>
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<tr>
<td>Intermediate egret (plumed egret)</td>
<td><em>Ardea intermedia</em></td>
<td>All year</td>
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<tr>
<td>Cattle egret</td>
<td><em>Ardea ibis</em></td>
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<tr>
<td>Striated heron (mangrove heron)</td>
<td><em>Butorides striatus</em></td>
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<tr>
<td>Nankeen night heron</td>
<td><em>Nycticorax caledonicus</em></td>
<td>All year</td>
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<tr>
<td>Black bittern</td>
<td><em>Ixobrychus flavicollis</em></td>
<td>All year</td>
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**Ibis & spoonbills**

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<tr>
<td>Glossy ibis</td>
<td><em>Plegadis falcinellus</em></td>
<td>All year</td>
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<tr>
<td>Australian white ibis</td>
<td>Threskiornis molucca</td>
<td>All year</td>
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<tr>
<td>Straw-necked ibis</td>
<td>Threskiornis spinicollis</td>
<td>All year</td>
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<tr>
<td>Royal spoonbill</td>
<td>Platalea regia</td>
<td>All year</td>
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<tr>
<td>Yellow-billed spoonbill</td>
<td>Platalea flaviga</td>
<td>Dry</td>
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**Storks**

Black-necked stork (jabiru)  | Ephippiorhynchus asiaticus | All year | * | ** | *** | *** |

**Kites, hawks & eagles**

Osprey                | Pandion haliaetus       | All year | *** | ** | * | ** |
Pacific baza (crested hawk) | Aviceda subcristata | All year | * | ** | * | ** |
Black-shouldered kite | Elanus axillaris       | All year | ** | ** | * | ** |
Letter-winged kite    | Elanus scriptus       | All year | * | ** | * | ** |
Square-tailed kite    | Lophoictinia isura     | Dry     | * | ** | * | ** |
Black-breasted buzzard | Ilamirostra melanosternon | All year | ** | * | * | * |
Black kite (fork-tailed kite) | Milvus migrans | Dry     | ** | * | ** | ** |
Whistling kite        | Haliaestur sphenurus   | All year | ** | *** | *** | *** |
Brahminy kite         | Haliaestur indus       | All year | ** | *** | ** | ** |
White-bellied sea-eagle | Haliaeetus leucogaster | All year | *** | ** | *** | *** |
Spotted harrier        | Circus assimilis       | Dry     | * | ** | * | ** |
Swamp harrier (marsh harrier) | Circus approximans | All year | * | ** | * | ** |
Brown goshawk          | Accipiter fasciatus   | All year | ** | *** | ** | * |
Grey goshawk (white goshawk) | Accipiter novaehollandiae | All year | ** | * | ** | * |
Collared sparrowhawk   | Accipiter cirrocephalus | All year | ** | * | ** | ** |
Red goshawk            | Erythrotriorchis radiatus | All year | * | * | ** | * |
Wedge-tailed eagle     | Aquila audax           | All year | * | ** | * | ** |
Little eagle           | Hieraaetus morphnoides | All year | * | ** | * | ** |

**Falcons**

Brown falcon          | Falco berigora        | All year | * | ** | *** | *** |
Australian hobby (little falcon) | Falco longipennis | All year | * | ** | ** | ** |
Grey falcon           | Falco hypoleucos      | Dry     | * | ** | * | ** |
Black falcon          | Falco subniger        | Dry     | * | ** | * | ** |
Peregrine falcon      | Falco peregrinus      | All year | ** | * | ** | ** |
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**Nankeen kestrel (Australian kestrel)** *Falco cenchroides* All year

**Cranes**

**Sarus crane** *Grus antigone* All year

**Brolga** *Grus rubicundus* All year

**Rails, crakes, swamphens & coots**

**Buff-banded rail (land rail)** *Rallus philippensis* All year

**Bush-hen** *Amaurornis olivaceus* Dry

**Bailon's crake (marsh crake)** *Porzana pusilla* Dry

**White-browed crake** *Porzana cinerea* All year

**Cheestnut rail** *Eulabeornis castaneoventris* All year

**Purple swamphen** *Porphyrio porphyrio* All year

**Eurasian coot** *Fulica atra* All year

**Bustards**

**Australian bustard** *Ardeotis australis* All year

**Button-quails**

**Red-backed button-quail** *Turnix maculosa* All year

**Little button-quail** *Turnix velox* All year

**Red-chested button-quail** *Turnix pyrrhotox* Dry

**Chestnut-backed button-quail** *Turnix castanotia* All year

**Turnstones, curlews, sandpipers & snipe**

**Latham's snipe** *Gallinago hardwickii* Dry

**Swinhoe's snipe** *Gallinago megala* Wet

**Black-tailed godwit** *Limosa limosa* Wet

**Bar-tailed godwit** *Limosia lapponica* Wet

**Little curlew (little whimbrel)** *Numenius minutus* Wet

**Whimbrel** *Numenius phaeopus* Wet

**Eastern curlew** *Numenius madagascariensis* Wet

**Marsh sandpiper** *Tringa stagnatilis* Wet

**Common greenshank** *Tringa nebularia* Wet
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<td>Currlew sandpiper</td>
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<td>Comb-crested jacana (lotus bird)</td>
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<td>Bush stone-curlew</td>
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<td>Beach stone-curlew</td>
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<td>Sooty oystercatcher</td>
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<td>Partridge pigeon</td>
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<td>Bar-shouldered dove</td>
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<td>Banded fruit-dove</td>
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<td>(black-banded pigeon)</td>
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<td>(red-crowned pigeon)</td>
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<td>(Torres Strait Pigeon)</td>
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<td>Brush cuckoo</td>
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<td>Black-eared cuckoo</td>
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<td>Rufous owl</td>
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<td>Mangrove gerygone (mangrove warbler)</td>
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<td>Pachycephala simplex</td>
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| Species                     | Scientific Name          | Availability | |
|-----------------------------|--------------------------|--------------||
| White-breasted whistler     | Pachycephala lanioides   | All year     | ** |
| Little shrike-thrush         | Colluricinia megarhyncha | All year     | *   | *** | ** |
| Sandstone shrike-thrush      | Colluricinia woodwardi   | All year     |     |     | *** |
| Grey shrike-thrush           | Colluricinia harmonica   | All year     | *** |     | ** |

**Monarchs, fantails, drongo & magpie larks**

| Species                     | Scientific Name          | Availability | |
|-----------------------------|--------------------------|--------------||
| Broad-billed flycatcher     | Myiagra ruficollis       | All year     | ** |
| Leaden flycatcher           | Myiagra rubecula         | All year     | *   | **  | *** | ** |
| Shining flycatcher          | Myiagra alecto           | All year     | *** | *** |   | ** |
| Restless flycatcher         | Myiagra inquiesta        | All year     | **  |     |   |   |
| Magpie-lark                 | Grallina cyanoleuca      | All year     |     | *** | *** | *** | ** |
| Rufous fantail              | Rhipidura rufifrons      | All year     | **  |     | *** | *** | ** |
| Grey fantail                | Rhipidura fuliginosa     | All year     | *   |     | *  |   |   |
| Northern fantail            | Rhipidura rufiventris    | All year     |     | *** | *** | *** | ** |
| Willie wagtail              | Rhipidura leucophrys     | All year     | **  |     | *** | *** | ** |
| Spangled drongo             | Dicrurus hottentottus    | All year     | *   |     | *** | *** | ** |

**Cuckoo-shrikes**

| Species                     | Scientific Name          | Availability | |
|-----------------------------|--------------------------|--------------||
| Black-faced cuckoo-shrike   | Coracina novaehollandiae | All year     | *   | *   | *** | **  | ** |
| White-bellied cuckoo-shrike | Coracina papuensis       | All year     | **  | *** | *** | **  | *** |
| Cicadabird                  | Coracina tenuirostris    | All year     |     | *** | *   |     |   |
| White-winged triller        | Lalage sueurii           | Dry          | *   | *   | *** |     | ** |
| Varied triller              | Lalage leucomela         | All year     | **  |     |     | *** |   |

**Orioles & figbirds**

| Species                     | Scientific Name          | Availability | |
|-----------------------------|--------------------------|--------------||
| Yellow oriole               | Oriolus flavicinctus     | All year     | *   | *** |   | *** |*** |
| Olive-backed oriole         | Oriolus sagittatus       | All year     | *   | *** | *   |   | ** |
| Figbird                     | Sphecotheres viridis     | All year     | *   | *** | *** | *** | ** |

**Woodswallows, butcherbirds**

<p>| Species                     | Scientific Name          | Availability | |
|-----------------------------|--------------------------|--------------||
| White-breasted woodswallow  | Artamus leucorynchus     | All year     | **  | **  | *   | *** | *** |
| Masked woodswallow           | Artamus personatus       | Dry          | *   |     |     |     |   |
| White-browed woodswallow     | Artamus superciliosus    | Dry          | *   |     |     |     |   |</p>
<table>
<thead>
<tr>
<th>Species</th>
<th>Scientific Name</th>
<th>Season</th>
<th>Coast</th>
<th>Mangrove</th>
<th>Rainforest</th>
<th>Open Woodland</th>
<th>Inland Waters &amp; Fringing Forests</th>
<th>Flood Plains</th>
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<tr>
<td>Black-faced woodswallow</td>
<td>Artamus cinereus</td>
<td>All year</td>
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<tr>
<td>Little woodswallow</td>
<td>Artamus minor</td>
<td>All year</td>
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<td>Black butcherbird</td>
<td>Cracticus guocyi</td>
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<td>Grey butcherbird</td>
<td>Cracticus torquatus</td>
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<tr>
<td>Pied butcherbird</td>
<td>Cracticus nigrogularis</td>
<td>All year</td>
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<td>Corvus orru</td>
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<td>Chlamydera nuchalis</td>
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<td>Singing bushlark</td>
<td>Mirafra javanica</td>
<td>All year</td>
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<td>Motacilla flava</td>
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<td>Double-barred finch</td>
<td>Taeniopygia bichenovii</td>
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<td>Long-tailed finch</td>
<td>Poephila acuticuada</td>
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<td>Masked finch</td>
<td>Poephila personata</td>
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<td>Crimson finch</td>
<td>Neochmia phaeon</td>
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<td>Neochmia rufigauda</td>
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<td>Yellow-rumped mannikin</td>
<td>Lonchura flavipryma</td>
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<td>Lonchura castaneothorax</td>
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### Swallows & martins

- **Barn swallow** (Hirundo rustica)  
  - Season: Dry  
  - Coast: *  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: *  
  - Escarpment & plateau: *

- **Welcome swallow** (Hirundo neoxena)  
  - Season: Dry  
  - Coast: *  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: *  
  - Escarpment & plateau: *

- **Tree martin** (Hirundo nigriceps)  
  - Season: All year  
  - Coast: ***  
  - Mangrove: **  
  - Rain forest: **  
  - Open woodland: ***  
  - Inland waters & fringing forests: ***  
  - Flood plains: ***  
  - Escarpment & plateau: **

- **Fairy martin** (Hirundo ariel)  
  - Season: Dry  
  - Coast: **  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: **  
  - Inland waters & fringing forests: **  
  - Flood plains: **  
  - Escarpment & plateau: *

### Old world warblers

- **Clamorous reed-warbler** (Acrocephalus stentoreus)  
  - Season: Dry  
  - Coast: **  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: *  
  - Escarpment & plateau: *

- **Tawny grassbird** (Megalurus timoriensis)  
  - Season: All year  
  - Coast: **  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: **  
  - Flood plains: ***  
  - Escarpment & plateau: *

- **Rufous songlark** (Cincloramphus mathewsi)  
  - Season: Dry  
  - Coast: **  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: *  
  - Escarpment & plateau: *

- **Brown songlark** (Cincloramphus cruralis)  
  - Season: Wet  
  - Coast: *  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: *  
  - Escarpment & plateau: *  

- **Zitting cisticola** (Cisticola juncidis)  
  - Season: All year  
  - Coast: **  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: ***  
  - Escarpment & plateau: *

- **Golden-headed cisticola** (Cisticola exilis)  
  - Season: All year  
  - Coast: **  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: ***  
  - Escarpment & plateau: *

### White-eyes

- **Yellow white-eye** (Zosterops luteus)  
  - Season: All year  
  - Coast: ***  
  - Mangrove: *  
  - Rain forest: *  
  - Open woodland: *  
  - Inland waters & fringing forests: *  
  - Flood plains: *  
  - Escarpment & plateau: **
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This is the book that Kakadu, with all its natural beauty and cultural and scientific interest, so richly deserves ... it is so well written and academically sound that it deserves a wide readership ... it should answer almost all the questions that might be reasonably expected from an intelligent and inquisitive visitor ... for the specialist in any particular field, it provides a fine introduction to each subject and a bibliography for further research.

Sir Edward Woodward

Kakadu is and always will be an important Australian place. Since it was proclaimed, the Park has hardly ever been out of the news or the political spotlight. It has generated intense debate over issues such as uranium mining and conservation, mining on Aboriginal land, tourism in World Heritage areas and the relationship between the Northern Territory and the Commonwealth.

It is a wonderful place: a landscape of beauty, starkness and drama; of living culture, history and prehistory; a place of abundant wildlife and scarcity; a land of floods, drought and fire. People have shaped its contents as much as the forces of wind, rain, fire and tide have moulded its form. For the Aboriginal traditional owners, Kakadu is not an exotic destination in remote Australia; it is their place, the land of their forebears and the future for their children. It represents a commitment by Aboriginal people to share their land and their cultural heritage with the world.

You will see a place that is very much a living landscape: one that has been occupied and used by Aboriginal people for up to 60 000 years. The Board of Management with its Aboriginal majority is one of the formal manifestations of the continuing management of the landscape by Aboriginal people. We welcome visitors to Kakadu: we want visitors to come and learn about this very special place. This book is one way that you can learn about Kakadu. We hope that by learning more you will appreciate the importance of Kakadu for its Aboriginal traditional owners, for us and for the people of Australia.

Brian Baruwei, Chair, Board of Management, Kakadu National Park

Kakadu is superbly represented in this scholarly work. It gives a range of scientific views of one of the most unique parts of the planet. It never ceases to surprise me how little is known about famous places of exceptional heritage value. This work has helped make amends in the case of Kakadu.

Robyn Williams, Science Unit, ABC Radio National

The Australian Nature Conservation Agency and the North Australia Research Unit of the Australian National University are pleased to be associated with the production of this book which should prove a valuable resource for policy makers, park managers, conservationists and academics alike.

This book can give those that want to dig deeper than the television documentary, see further than the bus window, and read more than the park pamphlet, something to bring with them when they visit or to take home to relive the experience.