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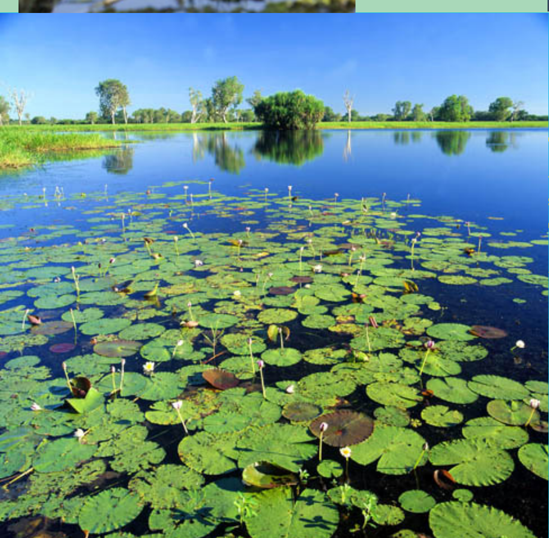
Department of Sustainability, Environment, Water, Population and Communities




Kakadu National Park
Ramsar Site

Ecological Character Description

Image credits: M. McAulay & DEWHA; J. Baker; S. Stuart-Smith; M. McAulay & DEWHA; B. Furby

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This information does not create a policy position to be applied in statutory decision making. Further it does not provide assessment of any particular action within the meaning of the EPBC Act, nor replace the role of the Minister or his delegate in making an informed decision on any action.

This report is not a substitute for professional advice rather it is intended to inform professional opinion by providing the authors' assessment of available evidence on change in ecological character. This information is provided without prejudice to any final decision by the Administrative Authority for Ramsar in Australia on change in ecological character in accordance with the requirements of Article 3.2 of the Ramsar Convention. Users should obtain any appropriate professional advice relevant to their particular circumstances.

Use of terms and information sources: All definitions and terms used in this draft report were correct at the time of production in June 2010. Refer to the References (Section 8) for works cited and Glossary (Section 8) for a list of key terms and terminology used.

Citation: This report can be cited as follows:

BMT WBM (2010) Ecological Character Description for Kakadu National Park Ramsar Site. Prepared for the Australian Government Department of Sustainability, Environment, Water, Population and Communities.

LIST OF ABBREVIATIONS

ANZECC/ARMCANZ:	Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand
ARRTC:	Alligator Rivers Region Technical Committee
ARR:	Alligator Rivers Region
BTEC:	Brucellosis and Tuberculosis Eradication Campaign
CAMBA:	China-Australia Migratory Bird Agreement
CDU:	Charles Darwin University
CEPA:	Communication, education, participation and awareness
CMS:	Convention on the Conservation of Migratory Species
CPUE:	Catch Per Unit Effort
CRC:	Cooperative Research Centre (for Tropical Savannas Management)
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
DSEWPAC:	Department of Sustainability, Environment, Water, Population and Communities
ECD:	Ecological Character Description
EPBC:	Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and regulations under that Act
eriss:	Environmental Research Institute of the Supervising Scientist
HAT:	Highest Astronomical Tide
IMCRA:	Integrated Marine and Coastal Regionalisation of Australia
IUCN:	International Union for Conservation of Nature
JAMBA:	Japan-Australia Migratory Bird Agreement
KMC:	Knowledge Management Committee
KRA:	Key Result Area
KRAC:	Kakadu Research Advisory Committee

LAC:	Limit(s) of Acceptable Change
MA:	Millennium Ecosystem Assessment
LAT:	Lowest Astronomical Tide
NES:	(matter of) National Environmental Significance
NLC:	Northern Land Council
NRM:	Natural Resource Management
NRETAS:	Northern Territory Department of Natural Resources, Environment, the Arts and Sport (previously NRETA)
NT:	Northern Territory
OSS:	Office of the Supervising Scientist
RIS:	Ramsar Information Sheet
ROKAMBA:	Republic of Korea- Australia Migratory Bird Agreement
sp.:	Species (singular)
spp.:	Species (plural)
TRaCK:	Tropical Rivers and Coastal Knowledge
TSSC:	Threatened Species Scientific Committee

EXECUTIVE SUMMARY

The Kakadu National Park Ramsar site is listed as a Wetland of International Importance under the "Convention on Wetlands of International Importance especially as Waterfowl Habitat" or, as it is more commonly referred to, the Ramsar Convention (the Convention).

This report provides the Ecological Character Description (ECD) for the Kakadu National Park Ramsar site, and has been prepared in accordance with the National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands (DEWHA 2008). This is the first ECD prepared for the site. In parallel with the preparation of the ECD, the Ramsar Information Sheet (RIS) for the site has been updated for submission to the Australian Government and Ramsar Secretariat.

The Kakadu National Park Ramsar site is located approximately 200 kilometres east of Darwin in the Northern Territory. The Kakadu National Park Ramsar site was historically two separate Ramsar sites within Kakadu National Park. These were Kakadu National Park (Stage I including wetland components of Stage III) and Kakadu National Park (Stage II). Kakadu National Park Stage I was originally listed as a Ramsar site in 1980 and expanded in 1995 to include wetland components of Stage III, while Stage II was listed in 1989 as a separate Ramsar site. The separate listing under the Stages reflected the historical listing of the area as a World Heritage site and a national park.

The Kakadu National Park (Stage I including wetland components of Stage III) Ramsar site comprised of all lands and waters in the eastern portion of the Kakadu National Park, following the eastern boundary of the Park along the East Alligator River and including the Nourlangie, Jim Jim and Barramundi Creeks. In 1995, the boundaries of site number two were extended to include only the wetland habitats within the eastern and southern areas of Kakadu National Park (Stage III).

Kakadu National Park (Stage II) Ramsar site encompassed all lands and waters situated in the northern and western part of the National Park, including the Wildman, West Alligator and South Alligator River systems and their floodplains, following the western Kakadu National Park boundary. The Stage II area also included both Field Island and Barron Island within Van Diemen Gulf to the low water mark.

In April 2010, the two Ramsar sites were merged together to form a single Ramsar site, called Kakadu National Park. In addition, the site was extended by approximately 600 000 hectares to include all remaining areas of Stage III. The merger and extension bought the Ramsar boundary in line with the existing boundary of the national park.

Ecological Character Descriptions describe the ecological character of a wetland at the time of its listing as a Wetland of International Importance. Although Kakadu National Park is now a single Ramsar site, it is important to report baseline data that reflects the different listing dates of the three Stages.

The Ramsar site is bounded by the following geographic features:

- Van Diemen Gulf and the Timor Sea in the north
- the East Alligator River and Arnhem Land in the east

- Wildman and Mary River catchments in the west, and
- Arnhem Land plateau to the south.

Approximately 50 percent of Kakadu National Park is Aboriginal land under the *Aboriginal Land Rights (Northern Territory) Act 1976*. Most of the remaining area of land is under claim by Aboriginal people. Title to Aboriginal land in the Park is held by Aboriginal Land Trusts that have leased their land to the Director of National Parks (under the *Environment Protection and Biodiversity Conservation Act 1999*) for the purpose of being managed as a Commonwealth Reserve. Land in the Park that is not Aboriginal land is vested in the Director.

The Kakadu National Park Ramsar site is composed of a diversity of coastal and inland wetland types. Wetland types present range from intertidal forested wetlands and mudflats, to seasonal freshwater marshes and permanent freshwater pools. Using the Ramsar typology, there are five coastal types and eight inland types within the Stage I and Stage III area. Within the Stage II area, there are nine coastal types and seven inland types.

The ECD has reviewed the Ramsar Nomination Criteria under which the two original Ramsar sites were listed as Wetlands of International Importance, and examined the applicability of the revised and new Criteria under the Convention that have been added since the sites were originally listed in 1980 and 1989. In this context, Kakadu National Park is now seen as meeting all nine Nomination Criteria of the Convention, recognising the representative wetland habitats of the site at a bioregional level, support of populations of vulnerable wetland species, its characteristics as a centre of endemism and high biodiversity including its diversity of habitats, support for key life-cycle functions such as waterbird breeding and refugia values, its importance for supporting substantial populations of waterbirds and fish diversity and fish nursery and spawning habitats and its support of at least one percent of the national population of several non-avian wetland species.

Critical components of the Ramsar site include key wetland habitats and populations of waterbirds, freshwater fish, aquatic invertebrates, turtle and crocodiles. The critical ecosystem processes that underpin the habitats of the Kakadu National Park Ramsar site include hydrology, fire regimes and notable biological processes, with supporting processes including climate, tidal hydraulics, groundwater, water quality, geology and geomorphology.

The wetland components and processes of the site support a broad range of ecosystem services/benefits including support of threatened fauna, support of endemic species, fisheries resource values and contemporary living culture. Additionally, cultural and socio-economic services are equally diverse, noting the particular importance of the wetlands of the site to the traditional owners and caretakers of Kakadu National Park (the 'Bininj'), as well as tourism and recreational values.

A summary of the critical services/benefits provided by the Kakadu National Park Ramsar site and the underlying critical ecosystem components and processes nominated by this ECD is given in Table E-1. The critical wetland services/benefits nominated were based on the attributes of the site described in the Ramsar Nomination Criteria as well as identifying critical 'cultural' services/benefits provided by the site in terms of human use. The critical wetland components and processes have been selected based on the particular characteristics of Kakadu National Park and on the basis that they underpin the critical services/benefits, but may also be critical in their own right.

As required by the National Framework document, the study has:

- sought to define the natural variability and limits of acceptable change (LACs) for the critical components, processes and services/benefits identified
- examined ecological character changes that have been observed or documented since listing of the sites in 1980 and 1989 (including assessment against relevant LACs), and
- investigated current and future threats to ecological character.

While the level of quantitative information and data needed to provide a more definitive assessment of ecological character change (and to set more definitive LACs as sought by the National Framework) are not available, it would appear unlikely that any of the LACs presented in the ECD have been meaningfully exceeded. It is noted however that saltwater intrusion processes have possibly degraded freshwater billabongs and other palustrine wetlands and *Melaleuca* communities.

The effect of saltwater intrusion in the floodplain areas of the Park has had the effect of changing the spatial characteristics and distribution of tidal creeks and associated mangrove environments over a long time period, often at the expense of predominantly freshwater systems. This includes the loss of several freshwater billabong environments located proximal to the tidal channels and at the fresh-salt interface areas of the major river systems, noting that these features have both ecological and cultural significance in terms of traditional food sources and traditional customary usage. However, the extent to which saltwater intrusion represents an ecological character change is difficult to assess noting that saltwater intrusion into Kakadu National Park's freshwater wetlands is a continuous natural process. A key factor to be considered is whether the environmental change or the rate of change can be perceived as having an anthropogenic source.

Recent or continuing threats that are notable in the context of the site that may affect future ecological character include:

- introduction and/or proliferation of exotic flora and fauna
- climate change
- tourism and recreational activities (including boating)
- mining activities
- damage to archaeological resources and rock art, and
- living resource extraction.

Of these threats, future impacts from climate change in terms of increased saltwater intrusion and impacts from the continuing persistence and spread of cane toads are seen as the most likely and potentially severe.

Information gaps, monitoring needs and recommendations in relation to communication, education, participation and awareness messages are also identified in the ECD. Key information gaps in the context of this ECD require:

- additional research and monitoring to establish an ecological character baseline for the key habitats

- better information and data sets about the presence and natural history of critical wetland species and their habitats including for example, surveys of threatened plant species, aquatic fauna species such as the river shark species and more systematic surveys of important avifauna and fish species and populations
- better information and understanding about the natural variability of wetland fauna populations and key attributes and controls on those populations
- additional investigation of the ecological character thresholds of particular habitats and communities to changes in key attributes/controls such as hydrology. The LACs stated in the ECD should be reviewed and revised as improved information becomes available, and
- more specific assessment of the vulnerability of the site to the impacts of climate change, and adaptation options that could be explored to reduce the future impacts.

In accordance with the above, monitoring needs and recommendations presented in this ECD relate broadly to obtaining data to assess future changes to ecological character as defined by the critical components, processes and services/benefits associated LACs for the site. Since the monitoring needs are quite extensive, a broad scale ecosystem health-based monitoring program may be most appropriate for the Ramsar site using lessons learned from similar approaches elsewhere. Emphasis should be placed on the collection of data and information about critical and supporting process indicators, such as water quality and biotic indicators of ecosystem health.

A combined set of communication, education, participation and awareness messages relevant to the ECD have been presented and can be used to communicate the importance of the site, why it was listed, possible changes to ecological character, the threats to the site and future actions required. These messages also serve as a summary of the key findings and conclusions of the ECD study.

Table E- 1 Summary of critical and supporting components, processes and services/benefits for the Kakadu National Park Ramsar site

	Components	Processes	Services/Benefits
Critical	C1 – Mangroves C2 – *Melaleuca* Forests C3 – Palustrine Wetlands and Billabongs C4 – Waterfalls, Seeps and Waterholes C5 – Populations of Migratory and Resident Waterbirds C6 – Populations of Freshwater Fish C7 – Populations of Freshwater and Saltwater Crocodiles C8 – Populations of Threatened Sharks C9 – Yellow Chat Populations C10 – Pig-nosed Turtle Populations C11 – Locally Endemic Invertebrate Species	P1 – Fluvial Hydrology P2 – Fire Regimes P3 – Breeding of Waterbirds P4 – Flatback Turtle Nesting	S1 – Maintenance of Global Biodiversity S2 – Fisheries Resource Values S3 – Contemporary Living Culture
Supporting	Seagrass Monsoon Rainforests and Riparian Vegetation Other Wetland Habitats Terrestrial Habitats Aquatic Invertebrates Regionally Endemic Species	Climate Geology/Geomorphology Tidal Hydraulics Water Quality Groundwater Ecosystem Processes	Recreation and Tourism Scientific Research and Education Historical Cultural Heritage Biological Products Sites/Items of Cultural Significance

1 INTRODUCTION

This Section provides general information about the Ecological Character Description (ECD) process and the Kakadu National Park Ramsar site.

1.1 Background

The Kakadu National Park Ramsar site was historically two separate Ramsar sites within Kakadu National Park. These were Kakadu National Park (Stage I including wetland components of Stage III) and Kakadu National Park (Stage II). Kakadu National Park Stage I was originally listed as a Ramsar site in 1980 and expanded in 1995 to include wetland components of Stage III, while Stage II was listed in 1989 as a separate Ramsar site. The separate listing under the Stages reflected the historical listing of the area as a World Heritage site and a national park.

The Kakadu National Park (Stage I including wetland components of Stage III) Ramsar site comprised of all lands and waters in the eastern portion of the Kakadu National Park, following the eastern boundary of the Park along the East Alligator River and including the Nourlangie, Jim Jim and Barramundi Creeks. In 1995, the boundaries of site number two were extended to include only the wetland habitats within the eastern and southern areas of Kakadu National Park (Stage III). Specifically, the Stage III area encompasses the in-stream waters, waterholes and associated tributaries of the South Alligator River commencing at the western border of Kakadu National Park Stage I and following the river corridors southwards to the headwaters, and including the wetlands located on the Marrawal Plateau.

Kakadu National Park (Stage II) encompassed all lands and waters situated in the northern and Western part of the National Park, including the Wildman, West Alligator and South Alligator River systems and their floodplains, following the western Kakadu National Park boundary. The Stage II area also includes both Field Island and Barron Island within Van Diemen Gulf to the low water mark.

In April 2010, the two Ramsar sites were merged together to form a single Ramsar site, called Kakadu National Park. In addition, the site was extended by approximately 600 000 hectares to include all remaining areas of Stage III. The merger and extension bought the Ramsar boundary in line with the existing boundary of the national park.

Kakadu National Park is co-managed by Indigenous owners and the Director of National Parks through a joint management board. Three excisions from the National Park and Ramsar site encompass mining lease areas (Uranium) and freehold land.

The Ramsar Convention sets out the need for contracting parties to conserve and promote wise use of wetland resources. In this context, an assessment of ecological character of each listed wetland is a key concept under the Ramsar Convention.

Under Resolution IX.1 Annex A: 2005, the ecological character of a wetland is defined as:

The combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.

The definition indicates that ecological character has a temporal component, generally using the date of listing under the Convention as the point for measuring ecological change over time. As such, the description of ecological character should identify a wetland’s key attributes and provide an assessment point for the monitoring and evaluation of the site as well as guide policy and management, acknowledging the inherent dynamic nature of wetland systems over time.

This is the first ECD document prepared for the site and although the document has been prepared for the whole of Kakadu National Park, it needs to draw on and identify baseline data from the different listing dates of the three Stages to provide appropriate assessment points for the monitoring and evaluation of the site. Although additional areas of Stage III were added to the Ramsar site in 2010, it is worth noting that the ‘wetland components’ of Stage III were already included in the Ramsar site in 1995. The 2010 extension of the site adds all other areas of Stage III into the Ramsar site consistent with the national park and World Heritage listing. Whilst ECDs describe the ecological character of a Ramsar site, they predominantly focus on the wetland values and characteristics that contributed to the site being listed as a Wetland of International Importance. As such, the ECD will retain a focus on the listing dates 1980, 1989 and 1995. Hereafter, the combination of all three Stages is referred to as the ‘Ramsar site’ or ‘Kakadu National Park’, with attention drawn to individual Stages as necessary.

The report has been prepared in accordance with the requirements of the National Framework and Guidance for Describing the Ecological Character of Australia’s Ramsar Wetlands (DEWHA 2008) (hereafter referred to as the National Framework). Further information about the requirements of the Framework is discussed in Section 1.2.

Note: Throughout this document, the term ‘Bininj’ is used to refer to traditional owners of Aboriginal land and traditional owners of other land in the Park, and other Aboriginals entitled to enter upon or use or occupy the Park in accordance with Aboriginal tradition governing the rights of that Aboriginal or group of Aboriginals with respect to the Park.

Bininj is a Kunwinjku and Gundjeihmi word, pronounced 'binn-ing'. This word is similar to the English word 'man' and can mean man, male, person or Aboriginal people, depending on the context. The word for woman in these languages is *Daluk*. Other languages in Kakadu National Park have other words with these meanings, for example the Jawoyn word for man is *Mungguy* and for woman is *Alumka*, and the Limilngan word for man is *Murlugan* and *Ugin-j* for woman. The authors have decided to use the term Bininj for the purposes of this Ecological Character Description.

1.2 Scope and Purpose of this Study

Figure 1-1 shows the key steps of the ECD preparation process from the National Framework document which forms the basis for ECD reporting. Based on the National Framework document (DEWHA 2008), the key purposes of undertaking an ECD are as follows:

1. To assist in implementing Australia’s obligations under the Ramsar Convention, as stated in Schedule 6 (Managing wetlands of international importance) of the Environment Protection and Biodiversity Conservation Regulations 2000 (Commonwealth):

a) To describe and maintain the ecological character of declared Ramsar wetlands in Australia *b) To formulate and implement planning that promotes:*

i) Conservation of the wetland

ii) Wise and sustainable use of the wetland for the benefit of humanity in a way that is compatible with maintenance of the natural properties of the ecosystem.

2. To assist in fulfilling Australia's obligation under the Ramsar Convention, to arrange to be informed at the earliest possible time if the ecological character of any wetland in its territory and included in the Ramsar List has changed, is changing or is likely to change as the result of technological developments, pollution or other human interference.

3. To supplement the description of the ecological character contained in the Ramsar Information Sheet submitted under the Ramsar Convention for each listed wetland and, collectively, to form an official record of the ecological character of the site.

4. To assist the administration of the Commonwealth Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act), particularly:

a) to determine whether an action has, will have or is likely to have a significant impact on a declared Ramsar wetland in contravention of sections 16 and 17B of the EPBC Act, or

b) to assess the impacts that actions referred to the Minister under Part 7 of the EPBC Act have had, will have or are likely to have on a declared Ramsar wetland.

5. To assist any person considering taking an action that may impact on a declared Ramsar wetland whether to refer the action to the Minister under Part 7 of the EPBC Act for assessment and approval.

6. To inform members of the public who are interested generally in declared Ramsar wetlands to understand and value the wetlands.

The key audiences for this document are expected to be:

- The Kakadu National Park Board of Management, the Director of National Parks and Parks Australia as the principal managers of Kakadu National Park.
- Bininj, as traditional owners and custodians of Kakadu National Park and its wetlands.
- The Northern Territory Government, the Natural Resource Management Board (Northern Territory) and local governments that make decisions that could affect the ecological character of the site.
- The Office of the Supervising Scientist (OSS) as the lead agency for science and research associated with uranium operations within and adjacent to the National Park and more generally in terms of tropical wetlands.
- DSEWPAC as the Administrative Authority for the Ramsar Convention in Australia.
- Other sectors of the community with a scientific or general interest in the Kakadu National Park Ramsar site.

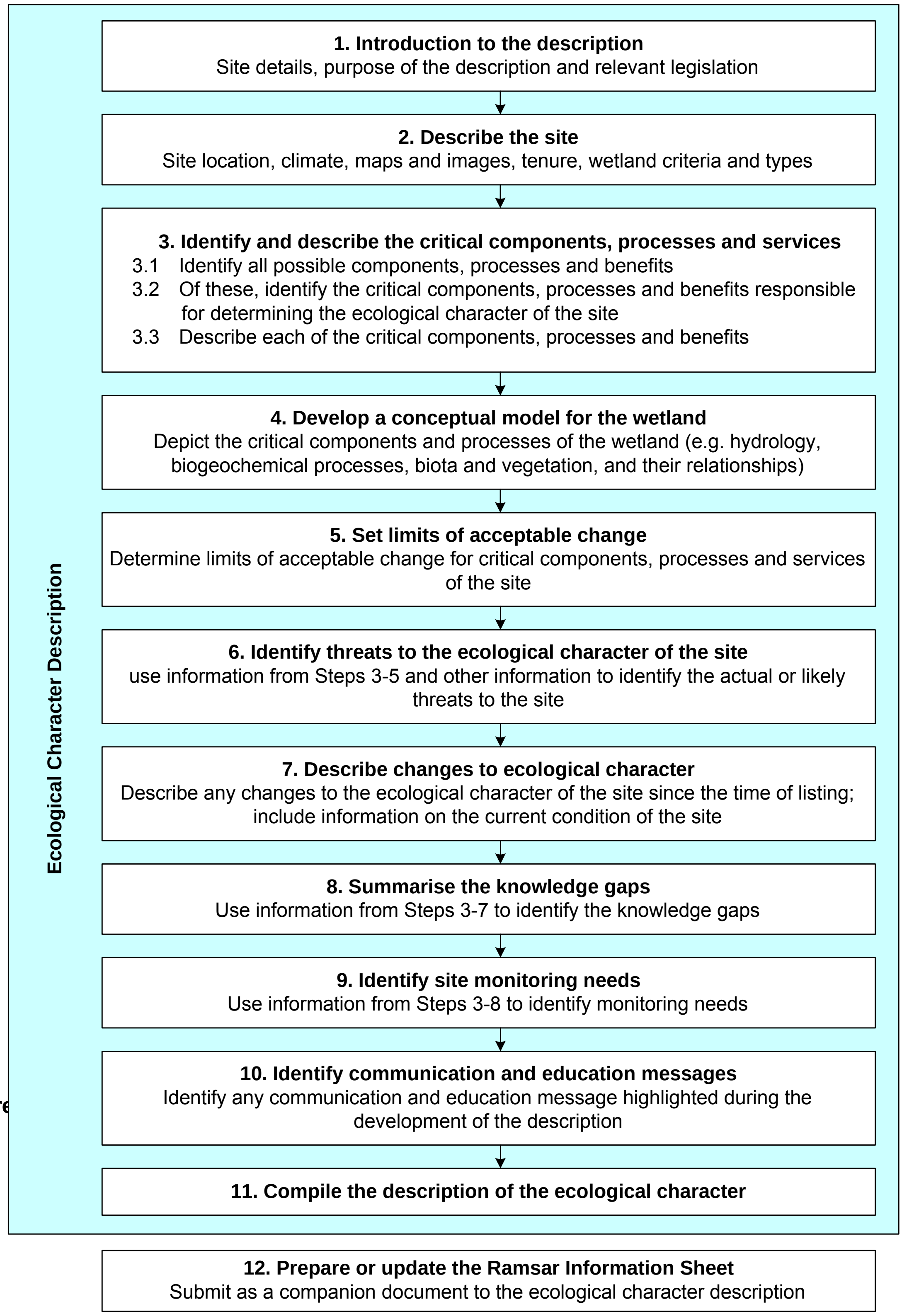

Ecological Character Description
1. Introduction to the description
Site details, purpose of the description and relevant legislation
2. Describe the site
Site location, climate, maps and images, tenure, wetland criteria and types
3. Identify and describe the critical components, processes and services
3.1 Identify all possible components, processes and benefits
3.2 Of these, identify the critical components, processes and benefits responsible for determining the ecological character of the site
3.3 Describe each of the critical components, processes and benefits
4. Develop a conceptual model for the wetland
Depict the critical components and processes of the wetland (e.g. hydrology, biogeochemical processes, biota and vegetation, and their relationships)
5. Set limits of acceptable change
Determine limits of acceptable change for critical components, processes and services of the site
6. Identify threats to the ecological character of the site
use information from Steps 3-5 and other information to identify the actual or likely threats to the site
7. Describe changes to ecological character
Describe any changes to the ecological character of the site since the time of listing; include information on the current condition of the site
8. Summarise the knowledge gaps
Use information from Steps 3-7 to identify the knowledge gaps
9. Identify site monitoring needs
Use information from Steps 3-8 to identify monitoring needs
10. Identify communication and education messages
Identify any communication and education message highlighted during the development of the description
11. Compile the description of the ecological character
12. Prepare or update the Ramsar Information Sheet
Submit as a companion document to the ecological character description

Figure … 2008)

1.3 Relevant Treaties, Legislation and Regulations

This section provides an overview of the treaties, legislation and regulations at various levels of government relevant to the Kakadu National Park Ramsar site.

1.3.1 Australian Government Legislation or Policy Instruments

EPBC Act

Australia's obligations to protect and maintain the ecological character of its Ramsar site is recognised in Commonwealth legislation through the EPBC Act. The EPBC Act sets out standards for managing Ramsar wetlands through the Australian Ramsar Management Principles (established within regulations under the Act) and through the referral and assessment of activities that may have an impact on Ramsar site and other matters of National Environmental Significance (NES).

Several of the matters of NES under the Act are directly relevant to the Kakadu National Park Ramsar site and are discussed in the sections below. These include:

- Wetlands of International Importance (Ramsar wetlands)
- Nationally threatened species and ecological communities
- World Heritage and National Heritage sites, and
- Commonwealth Reserves.

EPBC Act and Ramsar wetlands

As outlined in EPBC Act Policy Statement 1.1 (refer DEWHA 2009a), in the context of assessing significant impacts on the ecological character of Ramsar wetlands, actions that are considered to have an effect or potential effect on wetland ecological character involve the following:

- areas of the wetland being destroyed or substantially modified
- a substantial and measurable change in the hydrological regime of the wetland - for example, a substantial change to the volume, timing, duration and frequency of ground and surface water flows to and within the wetland
- the habitat or lifecycle of native species dependent upon the wetland being seriously affected
- a substantial and measurable change in the physico-chemical status of the wetland - for example, a substantial change in the level of salinity, pollutants, or nutrients in the wetland, or water temperature which may adversely impact on biodiversity, ecological integrity, social amenity or human health, and
- an invasive species that is harmful to the ecological character of the wetland being established in the wetland.

The Australian Government Minister for the Environment decides whether the action will, or is likely to, have a significant impact on the ecological character of the Ramsar wetland and whether the action will require approval under the EPBC Act. If approval under the EPBC Act is required, then an environmental assessment of the action must be carried out. The Minister decides whether to approve the action, and what conditions (if any) to impose, after considering the environmental assessment.

EPBC Act and protection of species listed under international conventions

Any action or potential action that may affect protected species or communities that are listed as threatened is also a matter of NES and must be referred to the Australian Government Minister for the Environment for assessment. The key international conventions on migratory species are briefly discussed below.

The Convention on the Conservation of Migratory Species of Wild Animals (also known as CMS or Bonn Convention) was adopted in 1979 and aims to conserve terrestrial, marine and avian migratory species throughout their range. It is an intergovernmental treaty under the United Nations Environment Program, concerned with the conservation of wildlife and habitats on a global scale.

The Japan-Australia Migratory Birds Agreement (JAMBA) and China-Australia Migratory Birds Agreement (CAMBA) are bilateral agreements between the governments of Japan and Australia and China and Australia, which seek to protect migratory birds in the East Asian - Australasian Flyway. The two agreements list terrestrial, water and shorebird species that migrate between Australia and the respective countries. In both cases the majority of listed species are shorebirds. Both agreements require the parties to protect migratory birds from take or trade except under limited circumstances, protect and conserve habitats, exchange information, and build cooperative relationships. The JAMBA agreement also includes specific provisions for cooperation on conservation of threatened birds.

In April 2002, Australia and the Republic of Korea also agreed to develop a bilateral migratory bird agreement similar to the JAMBA and CAMBA. The Republic of Korea-Australia Migratory Birds Agreement (ROKAMBA) agreement obliges its Parties to protect bird species which regularly migrate between Australia and the Republic of Korea, and their environment. The Annex to the ROKAMBA contains the list of species or subspecies of birds for which there is reliable evidence of migration between the two countries.

EPBC Act and Heritage

The Kakadu National Park was inscribed onto the World Heritage List in 1981 under both the cultural and natural criteria of the Convention. The specific Nomination Criteria under the World Heritage Convention that are also relevant to the site’s Ramsar listings include:

- Criterion (ii) - Outstanding example representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment.
- Criterion (iii) - Contain unique, rare or superlative natural phenomena, formations or features or areas of exceptional natural beauty.
- Criterion (iv) - Contain the most important and significant habitats where threatened species of plants and animals of outstanding universal value from the point of view of science and conservation still survive.

Kakadu National Park was also included on the National Heritage List in 2007 for its natural and cultural values.

EPBC Act and Management of Commonwealth Reserves

The Kakadu National Park is a Commonwealth Reserve under the EPBC Act declared for the purposes of:

- the preservation of the area in its natural condition, and
- the encouragement and regulation of appropriate use.

The EPBC Act sets out the following matters relevant to management of the reserve:

- establishment of the roles and responsibilities of the Director of National Parks (s514A)
- establishment of the roles and responsibilities of the Kakadu National Park Board of Management (s376)
- management planning (s367 – plans must be prepared under the Act and provide for the protection and conservation of the reserve), and
- control of actions in Commonwealth Reserves (s354 – through the prohibition and control of natural and cultural resources of the reserve).

Under the Act, the Director of National Parks generally has power to do all things necessary or convenient for performing the Director's functions which relate to administration, management and control of the Park. The Board of Management's functions under the Act are to make decisions relating to the management of the Park that are consistent with the Management Plan in operation for the park and, in conjunction with the Director, to prepare management plans for the Park, monitor the management of the Park and advise the Minister on all aspects of the future development of the Park (Director of National Parks 2007).

The EPBC Regulations provide for the controlling of activities within a Commonwealth Reserve, providing that it should take into account whether a proposed activity may interfere with the protection or conservation of biodiversity or heritage or with the continuing cultural use of the reserve by the traditional owners of the land (r12.03 EPBC Act). Certain prohibited actions must not be undertaken within Kakadu National Park except in accordance with the Management Plan (s354 EPBC Act). This includes killing, injuring or trading a member of a native species, damaging heritage, erecting a building or other structure, carrying out works, or taking an action for commercial purposes.

Kakadu National Park Management Plan 2007 – 2014

The Kakadu National Park Management Plan (Director of National Parks 2007) is the key document for on-ground management and planning in the Park and the conservation of its values. The Management Plan is set out under six key result areas (KRAs) that reflect the Parks Australia Strategic Planning and Performance Assessment Framework:

- KRA 1: Natural heritage management

- KRA 2: Cultural heritage management
- KRA 3: Joint management
- KRA 4: Visitor management and park use
- KRA 5: Stakeholders and partnerships, and
- KRA 6: Business management.

Aims, policies and actions (including annual programs of works at a district level within the Park) set the direction for management carried out to meet these KRAs. Annual reporting to the Australian Parliament is required on the outcomes of the KRAs in the Director of National Parks' Annual Report.

The Management Plan also outlines a specific process for assessment of proposals within Kakadu National Park. The process of assessment is based on three pre-determined categories of actions according to the degree of potential impact of the activity. Tables from the Management Plan outline the categories, impact assessment requirements, and matters for assessment, summarised as follows:

- Category 1 (least impact) proposals do not require assessment.
- Category 2 proposals require assessment by Park staff, the proponent or independent experts, following a procedure which outlines the values that are to be considered in the impact assessment.
- Category 3 (likely to have a significant impact) proposals are considered to possibly require referral and assessment pursuant to the EPBC Act.

National Parks and Wildlife Conservation Act

The *National Parks and Wildlife Conservation Act 1975* provided for the original declaration of the Kakadu National Park progressively between 1979 and 1991. The Act also established the Board of Management for the Park.

This Act was repealed and replaced by the EPBC Act in 2000 noting the roles and responsibilities of the Director of National Parks, the Kakadu National Park Board of Management, management planning and control of actions in the Park have been retained and are now administered under the provisions of the EPBC Act as outlined above.

Aboriginal Land Rights (Northern Territory) Act

As outlined in the Management Plan, approximately 50 percent of Kakadu National Park is Aboriginal land under the *Aboriginal Land Rights (Northern Territory) Act 1976*. Most of the remaining area of land is under claim by Aboriginal people.

Title to Aboriginal land in the Park is held by Aboriginal Land Trusts that have leased their land to the Director of National Parks for the purpose of being managed as a Commonwealth Reserve. Land in the Park that is not Aboriginal land is vested in the Director.

1.3.2 Northern Territory Legislation or Policy Instruments

In general, Northern Territory laws apply within the Kakadu National Park to the extent that those laws can operate concurrently with the EPBC Act and Regulations (Director National Parks 2007).

While the Northern Territory Planning Scheme (under the *Northern Territory Planning Act 1999*) applies generally to Kakadu National Park, the area is within an unzoned area under the Scheme, and as such the general performance criteria relating to development (such as building setback requirements in flood prone areas, vegetation clearance provisions, etc.) do not apply to development within Kakadu National Park.

Other Northern Territory legislation (for example, Waste Management and Pollution Control Act, Water Act, Weed Management Act) also applies generally to land and water management activities undertaken in Kakadu National Park and provides for protection of wetland and coastal environments from threatening activities and processes (ALGA 2006). However, integration between these pieces of legislation is regarded as weak in places (NTG, LCNT and NHT 2005).

Where practicable, the Management Plan provides guidance to ensure consistency with particular Northern Territory laws and policies, such as, for instance, setting bag limits for barramundi and other fish species consistent with Northern Territory bag limits.

In terms of infrastructure provision and management, the Northern Territory Government funds the management and maintenance of major roads into and out of the Park and Gunlom Road and also plays a role in implementing road safety measures (in consultation with the Director of National Parks). Jabiru is the largest settlement within the boundaries of the Ramsar site and the Jabiru Town Development Act (Northern Territory) establishes the Jabiru Town Development Authority which develops, maintains and manages the township.

Protection of wetland values through controls on development activities are also implemented within the West Arnhem Shire, which is approximately 49 236 square kilometres and covers the Kakadu National Park area. Although relatively few local government services are delivered by the local government within the Park, values within the area are recognised through a framework set up under the Local Government Regional Management Plan – Northern Region (Department of Local Government and Housing 2008), a statutory instrument under part 3.1 of the *Local Government Act 2008*.

The provision of services are noted within the Regional Management Plan to be subject to the rights and interests of Indigenous traditional owners (under the *Aboriginal Land Rights (NT) Act 1976* and the *Native Title Act 1993*), and a range of Northern Territory legislation (for example, Control of Roads Act, Disasters Act and Weeds Management Act) but it remains that Commonwealth legislation (EPBC Act) ultimately provides protection to both the cultural and natural values of the Park in delivery of the services.

Specific Northern Territory legislation that is potentially relevant includes the following:

- *Fisheries Act*
- *Territory Parks and Wildlife Conservation Act*

- *Local Government Act*
- *Mining Management Act*
- *Weeds Management Act*
- *Waste Management and Pollution Control Act,* and
- *Water Act.*

1.4 Key Terminology and Concepts

The Millennium Ecosystem Assessment (2003) provides definitions and descriptions of the characteristics of ecosystems and ecosystem services that should be used in the wise use of Ramsar wetlands. These definitions and concepts have been adopted by the National Framework (DEWHA 2008).

Within the Millennium Ecosystem Assessment (MEA), ecosystems are described as the complex of living communities (including human communities) and non-living environment (ecosystem components) interacting (through ecological processes) as a functional unit which provides a variety of benefits to people (ecosystem services). The sections below discuss key terms and concepts from the MEA and the National Framework used throughout the report. Specific definitions of these and other commonly used terms are contained in the Glossary in Section 7.

1.4.1 Wetland Processes

Wetland ecosystem processes are defined as the dynamic forces within the ecosystem between organisms, populations and the non-living environment. Interactions can be physical, chemical or biological. Examples include:

- climate – rainfall, temperature and evaporation
- hydrology – water balance, flooding and inundation regime
- geomorphology and physical processes – topography, soils, sedimentation processes and erosion
- energy and nutrient dynamics – primary production, decomposition and carbon cycle, and
- biological processes such as:

  (a) Biological maintenance – reproduction, migration, dispersal and pollination

  (b) Species interactions – competition, predation, succession, disease and infestation.

1.4.2 Wetland Components

Wetland ecosystem components are the physical, chemical and biological parts or features of a wetland. Examples include:

- physical form – wetland type, and geomorphology

- wetland soils – profiles, permeability and physico-chemical properties
- water quality – physico-chemical properties such as salinity or pH, and
- biota – flora, fauna and habitats.

It is noted in the National Framework that some components may be viewed as both wetland components and wetland processes (for example, geomorphology, water quality).

1.4.3 Wetland Services/Benefits

The terms 'benefits' and 'services' are defined within the National Framework in the context of the 'benefits that people receive from ecosystems'. The Millennium Ecosystem Assessment (2003) defines services as 'provisioning, regulating, and cultural services that directly affect people, and supporting services which are needed to maintain these other services.'

The Millennium Ecosystem Assessment (2003) identifies four types of services:

- provisioning services (products obtained from ecosystems) such as food and water
- regulating services (benefits obtained from the regulation of ecosystem processes) such as regulation of floods, drought, land degradation, and disease
- cultural services (non-material benefits through spiritual enrichment, cognitive development, reflection, recreation and aesthetic experiences) such as recreational, spiritual, religious and other non-material benefits, and
- supporting services (those necessary for the production of all other services) such as soil formation, nutrient cycling and primary production.

Supporting services differ from provisioning, regulating, and cultural services in that their impacts on people are either indirect or occur over a very long time (Millennium Ecosystem Assessment 2003). In the context of this ECD, ecological values (attributes relating to biological diversity) represent supporting services. The ecological values of wetlands are of indirect benefit to people in maintaining biodiversity.

The National Framework notes that wetland ecosystem services and benefits are based on or underpinned by wetland components and processes and can be both of direct benefit to humans (for example, food for humans or livestock) or of indirect benefit (for example, wetland provides habitat for biota which contribute to biodiversity).

1.4.4 Interaction of Wetland Elements

Figure 1-2 from the National Framework document shows a generic conceptual model of the interaction between ecosystem processes, components and services/benefits for a wetland. In general terms, the model shows how wetland ecosystem processes interact with wetland components to generate a range of wetland services/benefits. These services/benefits can be broadly applicable to all wetlands ecosystems (such as primary productivity) or specific to a given site (for example, breeding habitat for an important bird species or population).

1.4.5 Bioregionalisation Scheme

Guidelines under the Ramsar Convention favour the use of international or national biogeographic regions in the context of interpretation of Ramsar Nomination Criteria and other aspects of the Convention. Different biogeographic schemes apply to the site, depending on whether marine, terrestrial or freshwater environments are considered.

In this context, Kakadu National Park occurs within the following ‘biogeographic’ regions:

- Division VIII - Timor Sea Drainage Division (Wildman, South Alligator; East Alligator basins) (refer Figure 1-3), and
- Northern IMCRA Provincial Bioregion (IMCRA version 4, refer Figure 1-4).

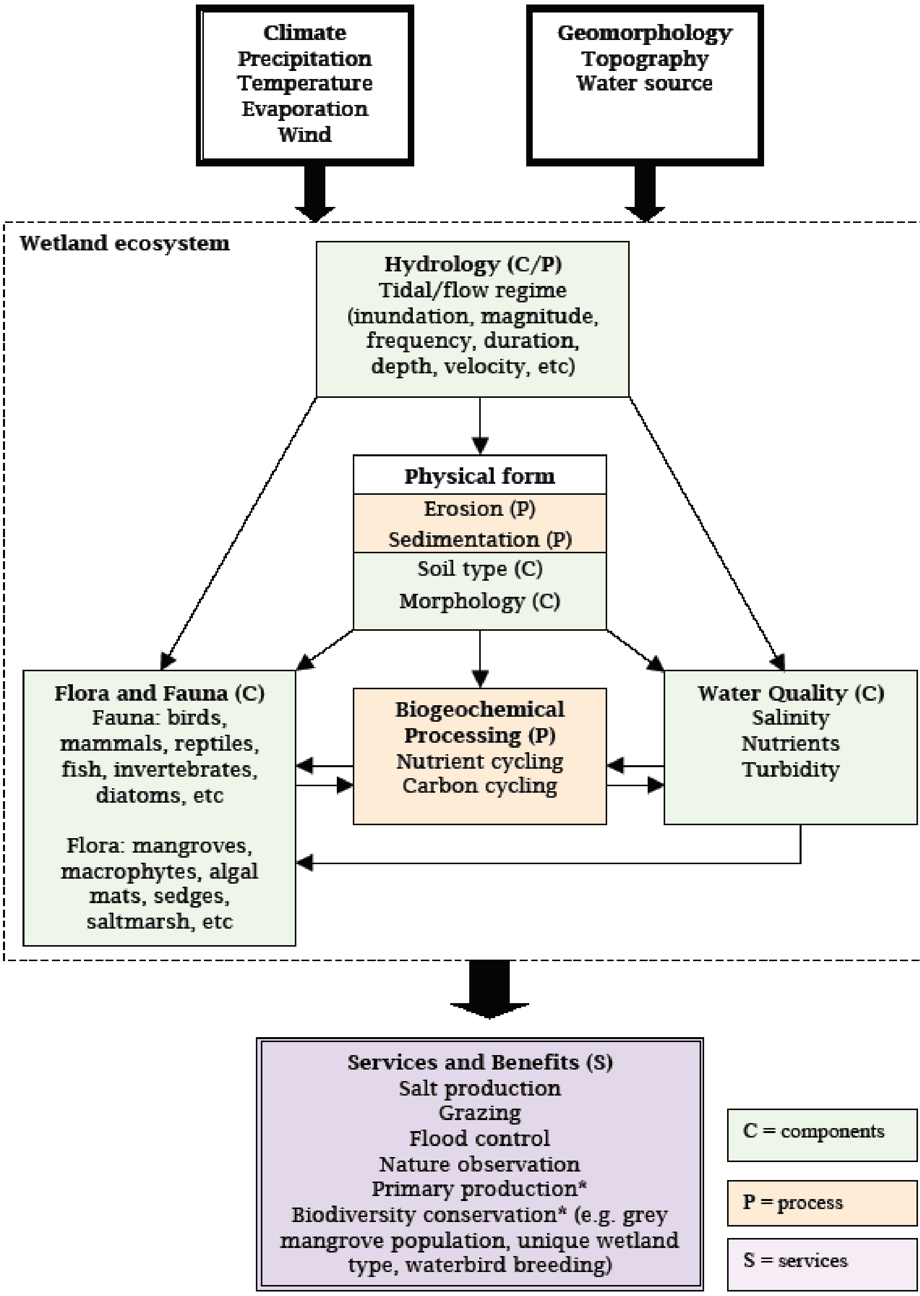


Figure 1-2 Generic conceptual model showing interactions between wetland ecosystem processes, components and services/benefits (source: DEWHA 2008)

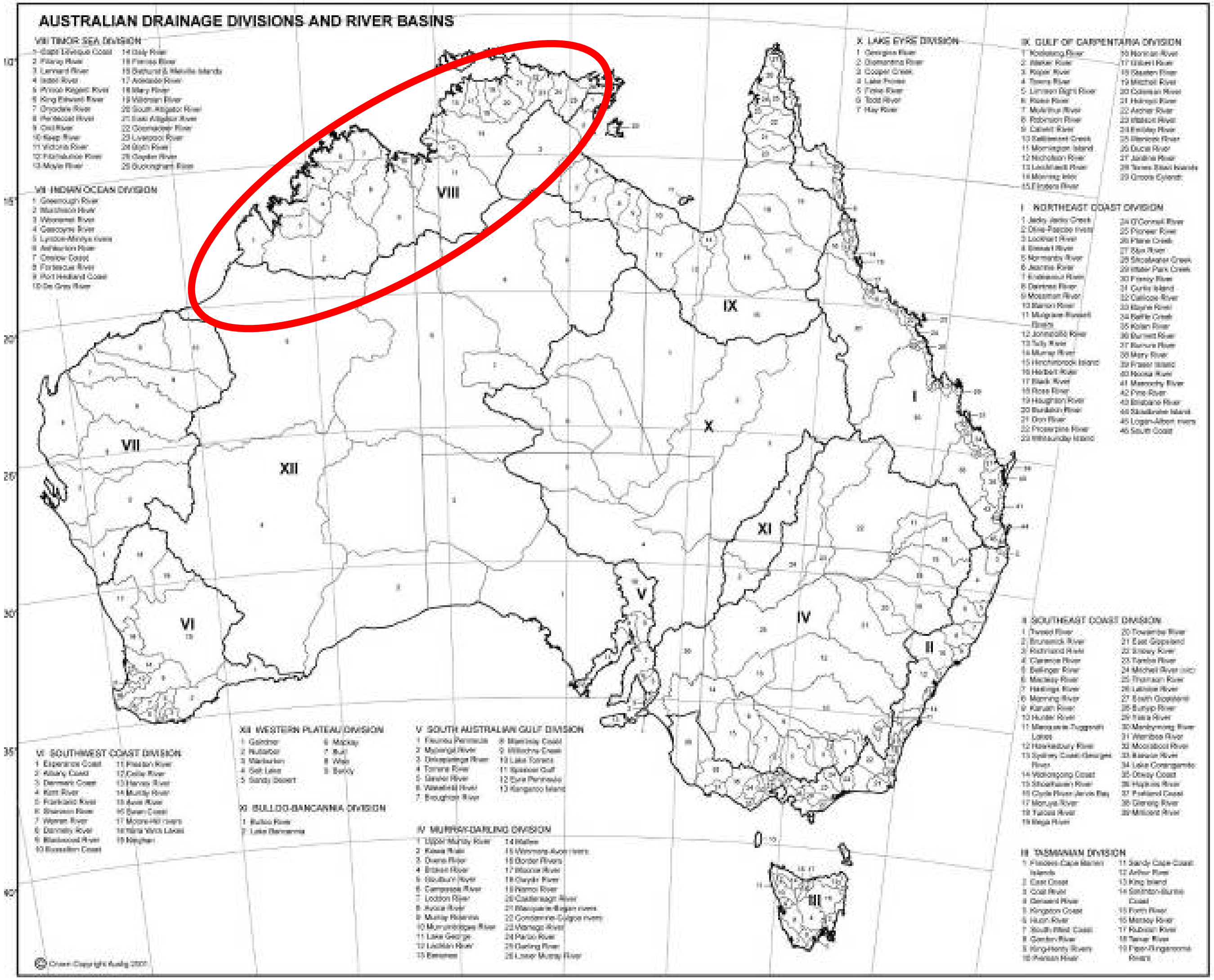


Figure 1-3 Australian drainage divisions, indicating the Timor Sea Drainage Division (number VIII) (source: Bureau of Meteorology undated)

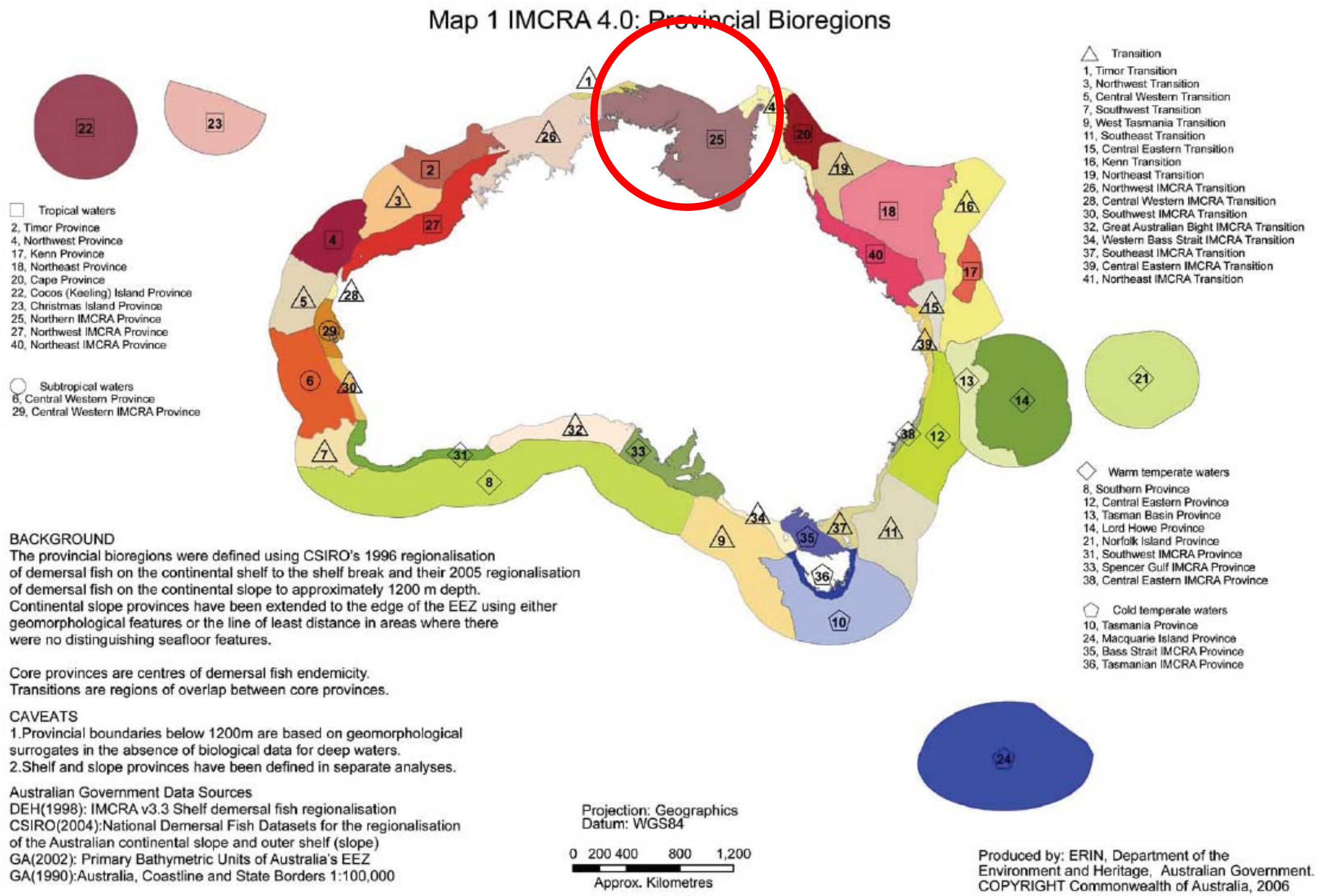


Figure 1-4

IMCRA provincial bioregions, indicating the Northern Provincial Bioregion (number 25) (source: Commonwealth of Australia 2006)

2 DESCRIPTION OF THE SITE

This Section of the ECD provides an overview of the site, including a brief description of the site, tenure and adjoining land use, an overview of the wetland types and a review of the site's Ramsar Nomination Criteria.

2.1 Details of the Site- Summary

Summary details of the site for the purposes of the ECD are provided in Table 2-1.

2.2 Location and Brief Description

The Kakadu National Park Ramsar site is located approximately 200 kilometres east of Darwin in the Northern Territory. The site extends from the coast in the north to the southern hills and basins 150 kilometres to the south, and stretch 120 kilometres latitudinally to the Arnhem Land sandstone plateau in the east (Director of National Parks 2007). A map showing the boundaries of the National Park and the historic boundaries of the three Stages is presented in Figure 2-1. It can be seen from the map that the site encompasses marine, estuarine, freshwater and terrestrial areas.

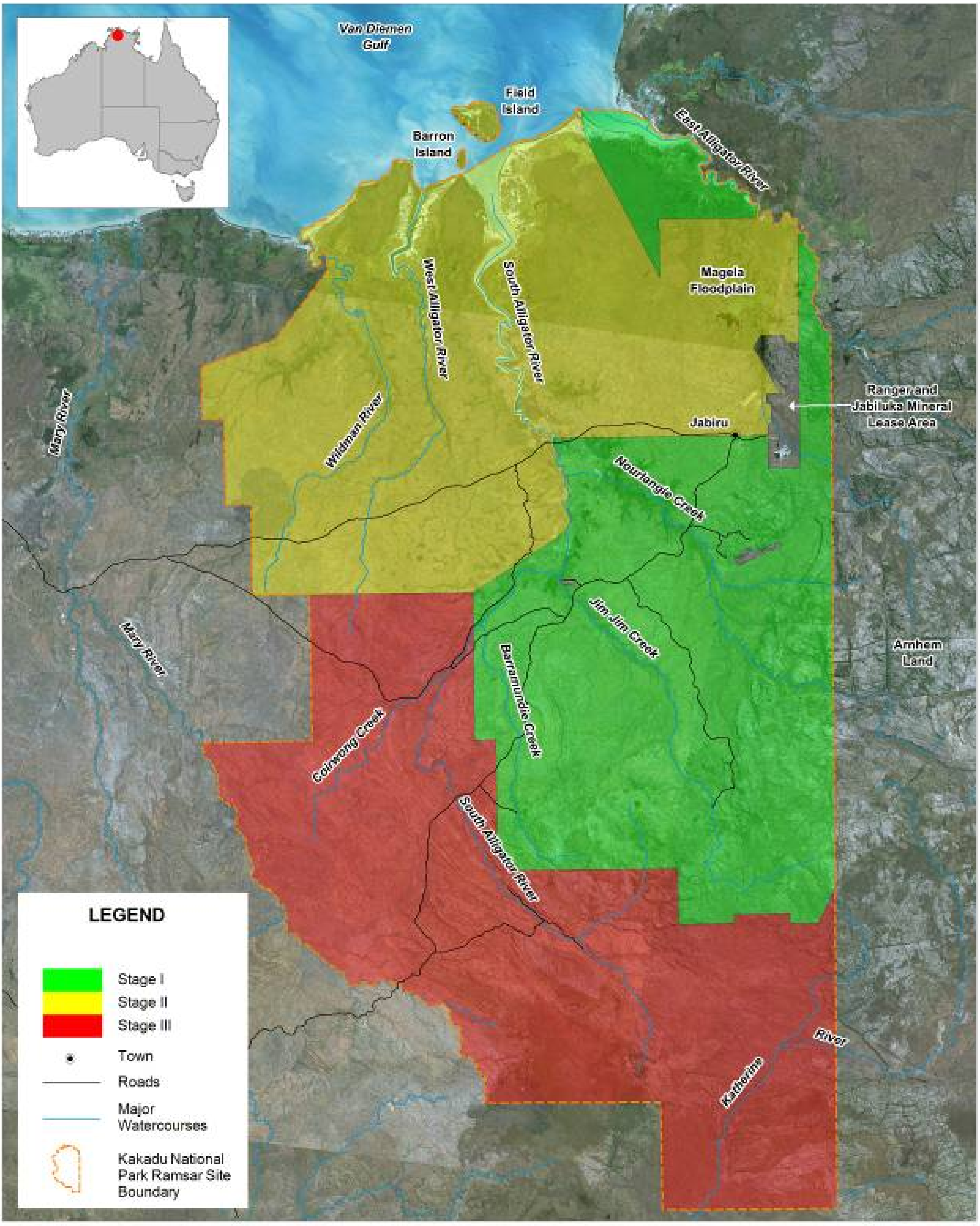
Stages I and II conformed to the Kakadu National Park boundaries. The 1995 addition of the wetland area located within Stage III encompasses the instream waters, waterholes and associated tributaries of the South Alligator River commencing at the western border of Kakadu National Park Stage I (at approximately 12°59' S, 132°21' E) following the river corridor southwards to its headwaters (at approximately 13°44' S, 132°43' E) and includes the ephemeral wetlands located on the Marrawal Plateau between approximately 13°44' S, 132°30' E and 13°48' S 132°34' E. The Stage III area also included the upper reaches of the Wildman, Mary, Katherine and West Alligator Rivers. It should be noted that all wetland dependent ecosystems within the Stage III boundary of Kakadu National Park were included in the Stage I and Stage III Ramsar site in 1995. Some of the notable waterbodies in the site are summarised in Table 2-2.

In April 2010, the two Ramsar sites were merged together to form a single Ramsar site, called Kakadu National Park. In addition, the site was extended by approximately 600 000 hectares to include all remaining areas of Stage III. The merger and extension bought the Ramsar boundary in line with the existing boundary of the national park. The Park boundaries are irregular in shape, and for descriptive purposes, the site coordinates provided in Table 2-1 are for an indicative bounding box that encompasses the entire site (as well as adjacent areas not located within the site). For a detailed description of the site boundaries, refer to the various Commonwealth gazette proclamations (Stage I – 1979; Stage II -1984, Stage III - 1987, Kakadu National Park proclamation amendment - 2007).

The township of Jabiru is the principal settlement found within the Ramsar site. Additionally, there are several areas within the boundaries of the Ramsar site where commercial development and associated accommodation is available, and Indigenous communities live in several outstations within the National Park (refer below for exclusions).

Table 2-1 Site details and location description for the Kakadu National Park Ramsar site, both historically (pre-merger) and current (merged sites)

Attribute	Kakadu National Park Ramsar site	Historic Stage I and III Ramsar site	Historic Stage II Ramsar site
Ramsar Site Number	• Site no. 204 (International List) • Site no. 2 (Australian List)	• Site no. 204 (International List) • Site no. 2 (Australian List)	• Site no. 441 (International List) • Site no. 30 (Australian List)
Location in coordinates	Indicative bounding box with the following co-ordinates: (i) 12°03'S, 131°53'E; (ii) 12°04'S, 133°00'E; (iii) 14°00'S, 132°59'E; (iv) 13°59'S, 131°51'E. The mid-point of this bounding box is 13°01'S, 132°26'E.	12º40'S; 132º45'E (1998 RIS)	12º30'S; 132º30'E (1998 RIS)
Area	Total site area: 1 979 766 hectares	Total site area: 683 000 hectares.	Total site area: 692 940 hectares.
Date of Listing	• Stage I listing in 12 June 1980. • Stage II listing in 15 September 1989. • Stage III wetland component extension in 1995. • Remaining area of Stage III extension in 2010.	• Stage I listing in 12 June1980. • Stage III wetland component extension in 1995.	15 September 1989
Dates Used for Ecological Character Description	• 1980 (time of listing for Stage I). • 1989 (time of listing for Stage II). • 1995 (time of listing for Stage III wetland components). • 1998 (time of RIS preparation). • 2010 (time of ECD preparation and Stage III extension).		
Justification for Date of Description	See above justification in parenthesis for various dates.		
Original Description Date	This is the first ECD undertaken for the site. As part of this project, the Ramsar Information Sheet (last updated in 1998) has been revised.		
Compiler's Name	BMT WBM Pty Ltd, with expert input from Austecology Pty Ltd and Melaleuca Enterprises, under contract to DSEWPAC.		
Ramsar Information Sheet	See the Australian Wetlands Database website: http://www.environment.gov.au/cgi-bin/wetlands/ramsardetails.pl?refcode=2#		
Management Plan	The principal Management Plan for the site is the Kakadu National Park Management Plan 2007-2014 (Director of National Parks 2007).		
Management Authority	The Ramsar site is located entirely within the boundaries of Kakadu National Park. The Park is managed under a joint management arrangement between the traditional owners and the Australian Government (Director of National Parks), through a Board of Management. The Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* and the *Aboriginal Land Rights (Northern Territory) Act 1976* provide the key legislative basis for the joint management of the Park.		



Title:

Location of the Kakadu National Park Ramsar Site Showing Historic Stages

Figure: **2-1**

Rev: **A**

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 20 40km

Approx. Scale

BMT WBM

www.bmtwbm.com.au

Filepath : I:\B17399_I_GML Kakadu Ramsar GWF\DRG\ECO_003_090805 Kakadu Stages.wor

The climatic zone within which the site is located is defined as the *hot humid summer* climatic zone (Stern *et al*. 2003). Whilst large expanses of the Ramsar site are Eucalypt-dominated woodlands, this ECD focuses specifically on the wetland habitats. The range of the environmental gradients and contiguous, diverse landscapes, have contributed to a variety of wetland habitat types that support high levels of biodiversity.

The Ramsar site is bounded by the following geographic features:

- Van Diemen Gulf and the Timor Sea in the north
- the East Alligator River and Arnhem Land in the east
- Mary River in the west, and
- Arnhem Land plateau to the south.

The site incorporates six catchments: Wildman River (most of catchment), West Alligator River (entire area), South Alligator River (entire area), East Alligator River (partial coverage) and the headwaters of Mary River (Mary River catchment) and Katherine River (Daly River catchment). Several drainages occur on Field Island; however, these appear to be mostly tidal drainage channels. Table 2-2 outlines the separation of the catchments between the three Stages.

Five major landscape types contain the diversity of wetland habitat types described in this document:

- Stone country – The sandstone escarpment area of Kakadu contains creeks, seeps and pools.
- Lowlands – The Eucalypt open woodlands and scrublands of the lowlands contains creeks.
- Southern hills and basins – the southern hills and basins contain creeks.
- Floodplains – The floodplains contain extensive freshwater wetlands including marshes, creeks and billabongs.
- Estuaries and tidal flats – The coastal habitats include intertidal mudflats, mangroves, saltmarsh, sandy shores and estuarine waters.

These landscape types contain a range of wetland ecosystem types that can be categorised into the following groups:

- <u>Terrestrial Ecosystems</u>: This includes both wetland areas, as well as extensive woodlands which occur throughout the site.
- <u>Floodplain Ecosystems</u>. Specifically, the vast tracts of palustrine wetlands that comprise the seasonally inundated floodplains, and the areas of *Melaleuca* swamp forest. Floodplain ecosystems support high numbers of flora and fauna populations/species that underlie a diversity of services.
- <u>River Channel</u>. River channels and the associated riparian vegetation support a diversity of fauna and flora species including threatened species, endemic species, waterbirds, fish and traditional foods. Furthermore, river channels provide opportunities for recreational/tourism activities.
- <u>Springs</u>. A number of groundwater fed springs occur in the site, with particularly notable examples occurring in the stone country and adjacent lowland areas.

- Billabongs. Billabongs are a particularly important feature of the floodplains. Specifically, billabongs provide areas of deep water habitat for aquatic flora and fauna, as well as dry season refuge for many of the aquatic fauna species that inhabit the floodplains. These fauna species include a diversity of freshwater fish, a large number of waterbirds, certain threatened species (for example, pig-nosed turtles) and a number of traditional food species (for example, file snakes and freshwater turtles). Furthermore, many traditional dietary staple plant species are associated with billabongs (for example, water lilies). Billabongs such as Yellow Water are also of value due to their tourism and recreational significance.
- Coastal/Marine Ecosystems. Specifically, intertidal mudflats, saltmarsh, mangroves and seagrass. Intertidal mudflats are notable as they support large aggregations of shorebirds.

Further discussion on these elements is provided throughout the report.

The Kakadu National Park Ramsar site displays significant cultural characteristics, having been continuously inhabited for at least 50 000 years (Roberts *et al*. 1993). An ongoing ‘living culture’ is maintained by the Bininj of Kakadu National Park today, with an evident fundamental connection between Bininj and wetlands within the landscape of the Ramsar site.

Table 2-2 Rivers and main streams within the site

Catchment	Key rivers/streams	Location within historic Ramsar sites
Wildman River catchment	• Wildman River • Cattle Creek • Leichhardt Creek • Alligator Creek	• Predominantly Stage II, headwaters in Stage III
West Alligator catchment	• West Alligator River • West Branch • East Branch • Flying Fox Creek	• Predominantly Stage II, headwaters in Stage III
South Alligator catchment	• South Alligator River • Stove Creek • Coirwong Creek • Gerowie Creek • Kumbolgie Creek • Waterfall Creek • Koolpin Creek • Fisher Creek • Barramudie Creek • Jim Jim Creek • Nourlangie Creek • Deaf Adder Creek	• Coastal areas and lowlands in Stage II • Nourlangie, Jim Jim and Barramundie Creeks sub-catchments mostly in Stage I • Upper South Alligator and Coirwong sub-catchment in Stage III
East Alligator catchment	• East Alligator River • Magela Creek • Coolobborie Brook	• Mostly Stage I, section near Ubirr in Stage II
Mary River catchment	• Mary River	• Headwaters in Stage III
Daly River catchment	• Katherine River • Gimbat Creek • Snowdrop Creek • Birdie Creek	• Stage III

2.3 Land Use and Tenure

2.3.1 Tenure and Land Use within the Site

Tenure

Approximately 50 percent of Kakadu National Park is Aboriginal land under the *Aboriginal Land Rights (Northern Territory) Act 1976*. Most of the remaining area of land is under claim by Aboriginal people.

Title to Aboriginal land in the Park is held by Aboriginal Land Trusts that have leased their land to the Director of National Parks (established under section 514A of the EPBC Act) for the purpose of being managed as a Commonwealth Reserve. Land in the Park that is not Aboriginal land is vested in the Director.

Stage I of Kakadu National Park was gazetted in April 1979 under the provisions of the *National Parks and Wildlife Conservation Act 1975*. Traditional owners leased Stage I lands to Director of National Parks and Wildlife Service for a period of 99 years.

Stage II of Kakadu National Park was gazetted in February 1984 under the provisions of the *National Parks and Wildlife Conservation Act 1975*, and amalgamated with Stage I to create a single Kakadu National Park in December 1985. The Director of National Parks has ownership over 93 percent of the land, whereas the remaining seven percent is vested with Jabiluka Aboriginal Lands Trust. In May 1991 an agreement was formalised to lease Aboriginal lands to the Director for the purposes of a national park.

Stage III of Kakadu National Park was proclaimed 1987, with later proclamations in 1989 and 1991 to increase the size the park, under the provisions of the *National Parks and Wildlife Conservation Act 1975*.

Land Use

Given that the Ramsar site is located entirely within the boundaries of the gazetted Kakadu National Park, the principal land uses are conservation management, tourism and education and low levels of hunting and gathering by traditional owners living within and around the Park.

2.3.2 Tenure and Land Use Adjacent to the Site

Tenure

The Ramsar site is bound by Arnhem Land to the east, most of which is held as the Arnhem Land Aboriginal Reserve. Van Diemen Gulf is situated to the north of the site and is Territory Waters (Crown land). Conservation reserves (declared under Northern Territory legislation), predominantly inactive pastoral leases and the Department of Defence Mount Bundey Training Area are situated to the west of the Ramsar site. Lands to the south of the Ramsar site include Nitmiluk National Park and Jawoyn Indigenous lands.

The Ranger uranium mine and Ranger and Jabiluka mineral leases are excluded from the boundaries of the National Park and the relevant Ramsar boundaries. Mining leases that historically allowed for mining in the southern area of the Park (South Alligator River Catchment) have not been active for some time.

Land Use

Key land use activities in the surrounding areas to the Kakadu National Park include:

- conservation management, tourism and education (within Northern Territory conservation reserves)

- uranium mining (undertaken at the Ranger uranium mine near the East Alligator River in the mineral lease area)
- historical mineral exploration (in the South Alligator River region), which has now been suspended
- commercial barramundi fishing in marine waters adjacent to the site
- grazing, and
- defence force training.

2.4 Description of Wetland Types

The Kakadu National Park Ramsar site is composed of a diversity of coastal and inland wetland types. Wetland types present range from intertidal forested wetlands and mudflats, to seasonal freshwater marshes and permanent freshwater pools. For this report, the Ramsar Classification System for Wetland Types (approved by Recommendation 4.7 and amended by Resolutions VI.5 and VII.11 of the Conference of the Contracting Parties) has been adopted.

There is generally a lack of detailed habitat and vegetation community mapping and spatially-referenced ecological data available for the Ramsar site. To date, no mapping according to Ramsar wetland typology has been undertaken for Kakadu National Park. Relevant mapping data at a whole-of-site scale includes:

- broad-scale (1:1 000 000) vegetation mapping (Wilson *et al.* 1990)
- more detailed (1:100 000) mapping for mangroves (provided by Parks Australia) and *Melaleuca* forest (Brocklehurst and van Kerckhof 1994)
- mapping of billabongs (digitised for part of the area by BMT WBM 2010 from 1:250 000 topographical mapping, aerial photography and a Digital Elevation Model), and
- seagrass mapping undertaken by Roelofs *et al.* (2005).

Numerous other mapping studies provide partial coverage of the site, such as mapping of vegetation communities in the Magela Creek sub-catchment (for example, Finlayson *et al.* 1989).

These data sources, together with other information describing the habitats and communities of the site (for example, Finlayson *et al.* 1988, Finlayson and Woodroffe 1996, Cowie *et al.* 2000, Finlayson 2005), have been considered for this report in order to determine Ramsar wetland types present within the site. Further details and descriptions of these wetland types are provided below and summarised in Table 2-3 and Table 2-4.

Note that there are some uncertainties regarding the extent and distribution of most wetland types due to the lack of a consistent, systematic mapping of Ramsar wetland habitat types within the site. Where such uncertainties exist, these have been identified in the following sections, including a discussion on discrepancies between wetland types identified as present in the 1998 RISs and those identified by this study. Further, note that this section serves to provide a description of wetland types, while particular values of the wetlands have been highlighted elsewhere in the document where relevant (for example, justification for Nomination Criteria in Section 2.5, descriptions of critical components, processes and services/benefits in Section 3).

Table 2-3 Coastal wetland types and representative examples within Kakadu National Park Ramsar site

Ramsar wetland type	Representative examples
A - Permanent shallow marine waters in most cases less than 6 m deep at low tide; includes sea bays and straits. (i.e. not intertidal)	Absent - Site boundaries extend to the low water mark, therefore no permanent subtidal marine waters are present. Subtidal waters within rivers are classified as estuarine waters (Type F).
B - Marine subtidal aquatic beds; includes kelp beds, sea-grass beds, and tropical marine meadows.	Present - Seagrass beds are mapped around Field Island; small patches occur elsewhere along coastline. Area is unknown specifically within Ramsar site, but in Van Diemen Gulf 2126 ha [A]
C - Coral reefs	Absent - Rocky shores and reefs contain corals, but no coral (carbonate) reefs present.
D - Rocky marine shores; includes rocky offshore islands, sea cliffs.	Present - Rocky shoreline along West Alligator Head, Barron Island and Field Island. Shoreline length approximately 3.2 km [B]
E - Sand, shingle or pebble shores; includes sand bars, spits and sandy islets; includes dune systems and humid dune slacks.	Present - Pococks and Middle Beach (West Alligator Head), western shoreline of Barron Island, small sandy beach landward of mangroves at mouth of South Alligator River. Shoreline length approximately 18.5 km [B]
F - Estuarine waters; permanent water of estuaries and estuarine systems of deltas.	Present - Tidal sections of Wildman, West Alligator, South Alligator Rivers, and the upper estuary of East Alligator River.
G - Intertidal mud, sand or salt flats.	Present - Coastal shoreline between Wildman River mouth and East Alligator River mouth (Point Farewell), Field and Barron Islands.
H - Intertidal marshes; includes salt marshes, salt meadows, saltings, raised salt marshes; includes tidal brackish and freshwater marshes.	Present - Extends along coastline and into the estuarine areas Wildman, East Alligator, West Alligator, South Alligator Rivers, and Point Farewell.
I - Intertidal forested wetlands; includes mangrove swamps, nipah swamps and tidal freshwater swamp forests. (i.e. Mangroves and Melaleuca)	Present - Extends along coastline and into the estuarine areas Wildman, East Alligator, West Alligator, South Alligator Rivers, and Point Farewell. Area: 8689 ha [C]
J - Coastal brackish/saline lagoons; brackish to saline lagoons with at least one relatively narrow connection to the sea.	Present - Saline lagoon at northern tip of Field Island; broader distribution within the site unknown.
K - Coastal freshwater lagoons; includes freshwater delta lagoons.	Present - Chenier ridges at Pococks and Middle Beaches reportedly contain freshwater lagoons.
Zk(a) – Karst and other subterranean systems	None mapped or known.
Total marine/coastal wetland types	**9**

A = Roelofs *et al.* (2005) – note includes areas outside but contiguous with the site; B = Smartline mapping; C = Mangrove mapping from Parks Australia;

Table 2-4 Inland wetland types and representative examples within Kakadu National Park Ramsar site

Ramsar wetland type	Representative examples
L - Permanent inland deltas.	Present - Yellow Water.
M - Permanent rivers/streams/creeks; includes waterfalls.	Present - e.g. Gubara, Ikoymarrwa, Fern Gully, Koolpin, Radon, Gerowrie, Wildman, West Alligator, South Alligator and South Alligator Rivers.
N - Seasonal/Intermittent/ irregular rivers/ streams/ creeks.	Present - Widespread in upper reaches of all catchments, e.g. Plum Tree Creek.
O - Permanent freshwater lakes (greater than 8 ha); includes large oxbow lakes.	Present - e.g. Leichhardt Billabong, Chirracarwoo Lagoon, Yellow Water, Red Lily, Mamukala, Alligator Billabong, Two Mile Hole, and Palm Swamp
P - Seasonal/intermittent freshwater lakes (less than 8 ha); includes floodplain lakes.	None mapped or known. Note that lakes are considered to be open water features with little vegetation. Intermittent billabongs in the site generally have high vegetation cover, and therefore more conform to type Ts.
Q - Permanent saline/brackish/alkaline lakes.	None mapped or known. Inland waterbodies generally fresh, although brackish lagoons occur in coastal areas (see Table 2-3).
R - Seasonal/intermittent saline/brackish/ alkaline lakes and flats.	None mapped or known. See comment above for type Q.
Sp - Permanent saline/brackish/alkaline marshes/pools.	None mapped or known. See comment above for type Q.
Ss - Seasonal/intermittent saline/brackish/alkaline marshes/pools.	None mapped or known. See comment above for type Q.
Tp -- Permanent freshwater marshes/pools; ponds (less than 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.	Present - Widespread throughout floodplain of all catchments, e.g. Couramoul Waterhole.
Ts - Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.	Present - Widespread throughout floodplain of all catchments.
U - Non-forested peatlands; includes shrub or open bogs, swamps, fens.	None mapped or known.
Va - Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.	None mapped or known.
Vt - Tundra wetlands; includes tundra pools, temporary waters from snowmelt.	None mapped or known.
W -- Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.	None mapped or known.
Xf - Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.	Present - Widespread throughout floodplain of all catchments. *Melaleuca* = 74 113 ha[D]
Xp - Forested peatlands; peatswamp forests.	None mapped or known.
Y - Freshwater springs; oases.	Present - e.g. Pheasant Brook, Kanalada Brook, Bellyungardy Spring, Lone Spring.
Zg - Geothermal wetlands	None mapped or known.
Zk(b) – Karst and other subterranean hydrological systems, inland	None mapped or known.
Total Inland Wetland Types	**8**

D = Brocklehurst and van Kerckhof (1994)

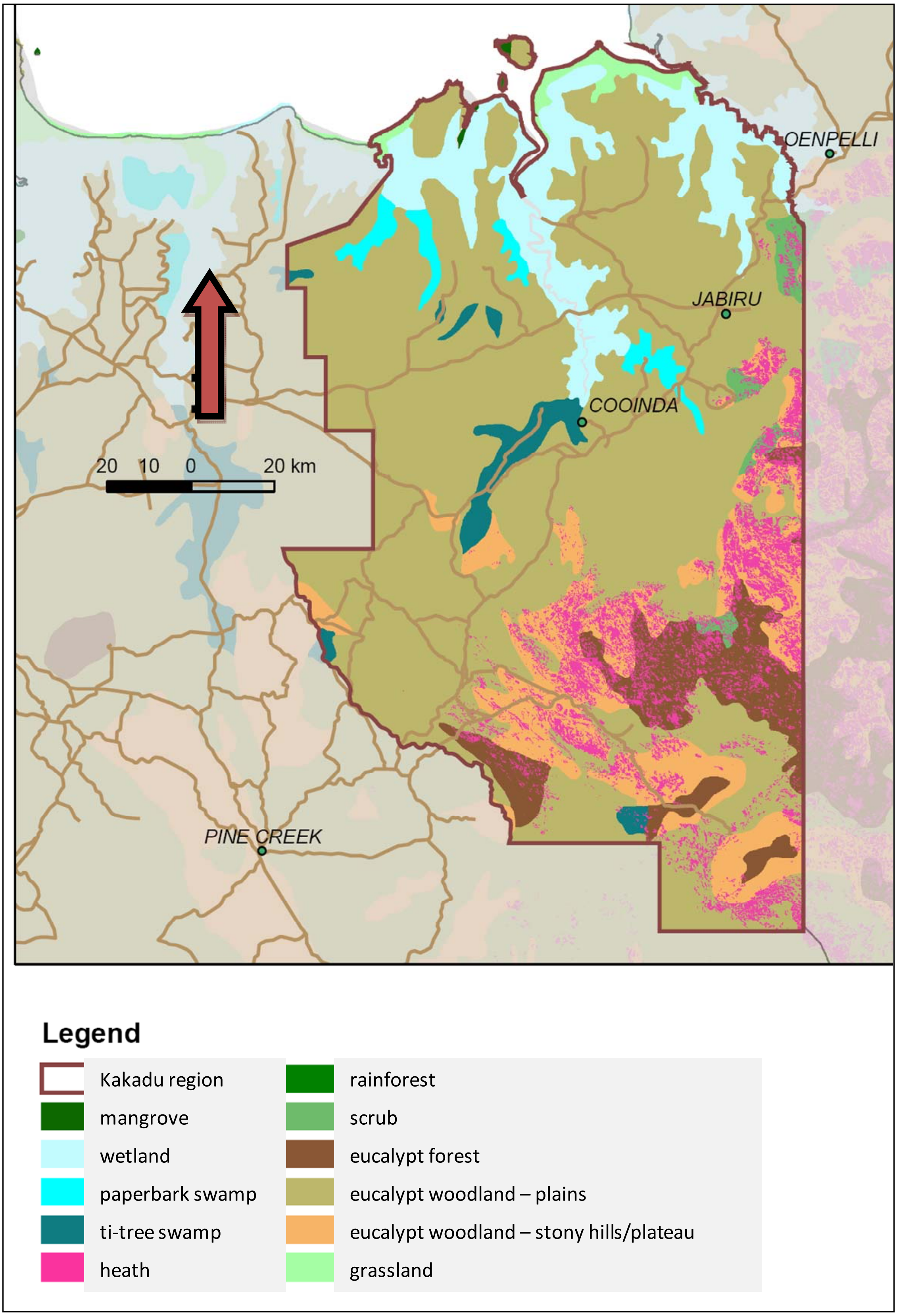


Figure 2-2 Vegetation map for the Ramsar site (source: Tropical Savannas CRC undated)

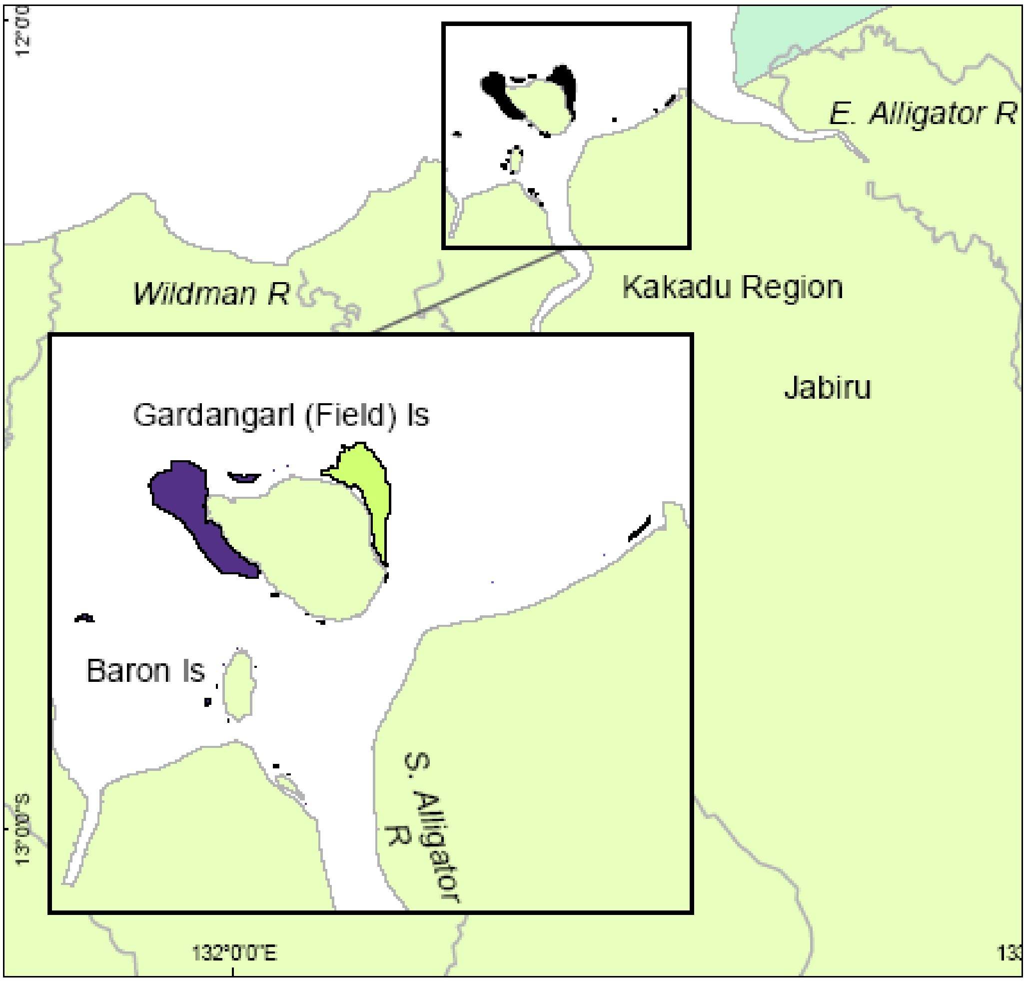
Note that 'Kakadu region' as referenced in the legend is synonymous with the Kakadu National Park boundary.

2.4.1 Marine / Coastal Wetland Types Present

Type B: Marine subtidal aquatic beds

This wetland type is represented by intertidal seagrass communities. A seagrass survey that incorporated the Ramsar site mapped approximately 2126 hectares of seagrass beds in the Van Diemen Gulf (Roelofs *et al.* 2005, refer Figure 2-3). Almost all of this seagrass occurred around Field Island, with seagrass beds comprised of *Halophila ovalis* on the north-western shoreline and a mixed bed of *H. ovalis* and *Halodule uninervis* on the north eastern shoreline. Elsewhere, small patches of seagrass were recorded around Barron Island, the mouth of South Alligator River and Cape Farewell. Note, however, that only a small proportion of the seagrass occurs within the site, as the Ramsar site boundary extends to the low water mark.

Small patches of seagrass are also thought to be present within the Ramsar site, although seagrass patches were too small to be mapped by Roelofs *et al*. (2005).



Purple = *Halophila ovalis*; Green = *H. ovalis* + *Halodule uninervis*

Figure 2-3 Distribution of seagrass beds within and adjacent to the Ramsar site (source: Roelofs *et al.* 2005)

Halophila ovalis

Halodule uninervis

Figure 2-4 Seagrass species occurring within the Ramsar site (source: BMT WBM)

Type D: Rocky marine shores

This wetland type is characterised by exposed rocky marine shores, including rocky offshore islands and sea cliffs. Although not listed in the 1998 RIS for either of the historic (pre-merger) Ramsar sites, Smartline mapping indicates that approximately 3.2 kilometres of rocky shorelines are present in along West Alligator Head, Barron Island and Field Island (refer Figure 2-5). It should be noted that these Smartline data have not been ground-truthed in detail within the site, although rocky shores are known to occur at all these locations (S. Winderlich, KNP pers. comm. 2010).

Type E: Sand, shingle or pebble shores

This wetland type includes sand bars, spits and sandy islets, as well as dune systems and humid dune slacks. Sandy beaches occur along the eastern and northern shores of Field Island and the western shoreline of Barron Island, as well as at West Alligator Head on the mainland (Pococks and Middle Beach). These sandy beaches are important nesting sites for flatback turtles. A small sandy beach is also present on the landward side of the mangroves at the mouth of the South Alligator River (Figure 2-5). While sediments along the mainland foreshore contain sand (and mud), these have been colonised by mangroves and are therefore not considered to represent sandy shores.

It should be noted that reliable mapping of sandy shores within the site is not available. The map presented in Figure 2-5, which is based on broad-scale mapping undertaken as part of the national Smartlines mapping project (available from http://www.ozcoasts.org.au/coastal/smartline.jsp#) should be considered as indicative only.

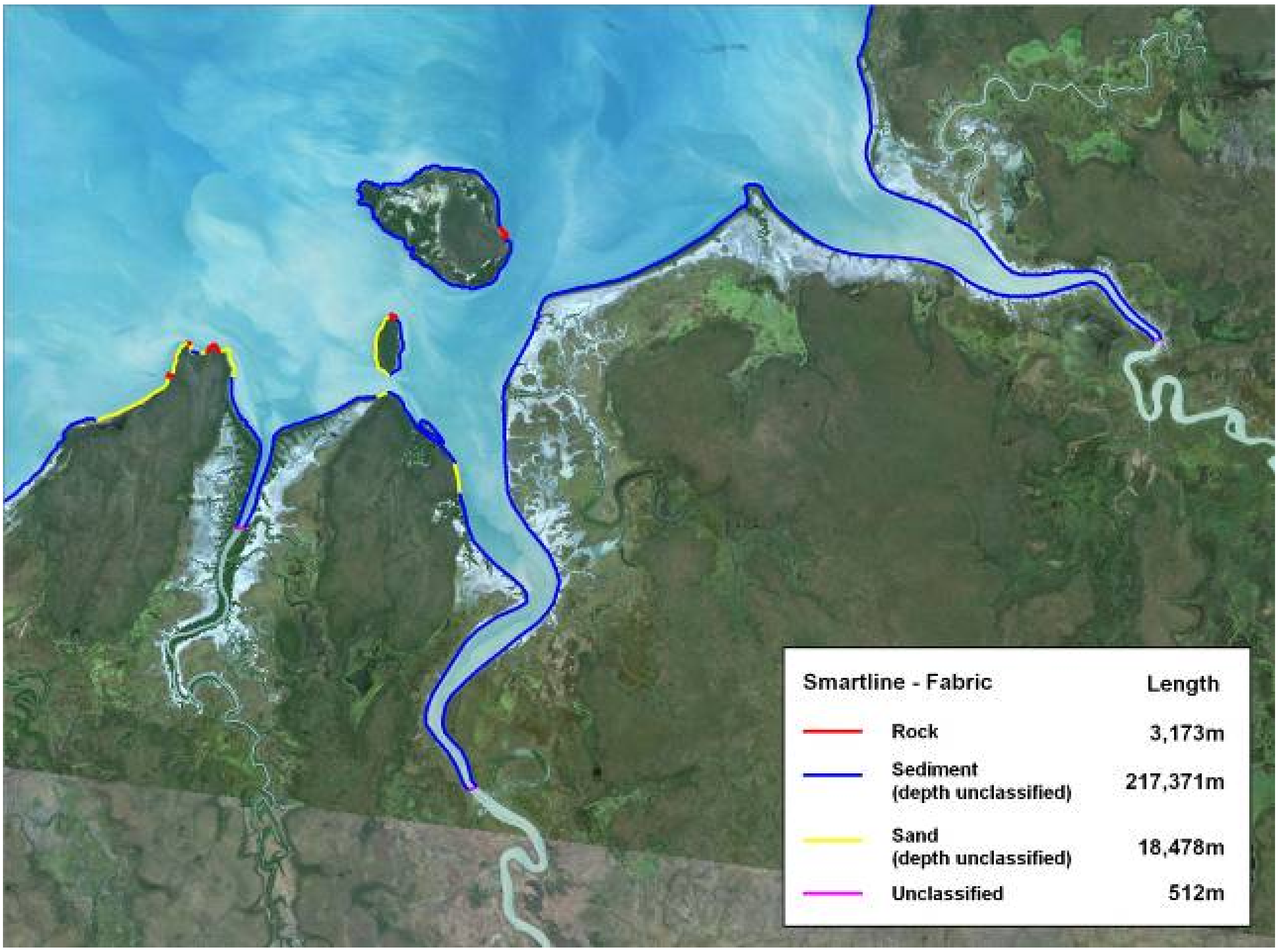


Figure 2-5 Smartline mapping of backshore habitats within the Ramsar site (source: GeoSciences Australia undated)

<u>Type F: Estuarine waters</u>

This wetland type includes permanent waters of estuaries and estuarine systems of deltas. Determining the extent and distribution of estuarine waters is to a large extent dependent on the definition of an estuary. For the purposes of this study, estuarine waters are considered here to include the freshwater/marine interface area within creeks and rivers. It is represented in the estuarine waters are present in the tidal section of the Wildman, East Alligator, West Alligator and South Alligator Rivers.

Figure 2-6 Estuarine waters of the South Alligator River (source: BMT WBM)

Type G: Intertidal mud, sand or salt flats

This wetland type encompasses habitats comprised of deposits of sand and mud that accumulate on intertidal flats. Extensive intertidal mudflats extend along most of the coastline of the Ramsar site. When exposed during low tides, these tidal flats form important feeding areas for large aggregations of shorebirds. Broad, low-lying hypersaline mudflats that are largely unvegetated also adjoin tidal reaches of the rivers and creeks. These tidal flats occur on the landward side of mangrove communities, and often form habitat mosaics with intertidal marshes and mangroves (Figure 2-7).

Type H: Intertidal marshes

This wetland type is represented in the Ramsar site by saltmarsh (samphire) communities that inhabit salt-flats in the coastal zone, and also fringe lower estuarine sections of the main channels (Figure 2-7). Saltmarsh communities are floristically poor, with succulent shrub species present including *Tecticornia indica, Suaeda arbusculoides, Tecticornia australasica* and *Sesuvium portulacastrum*, and grasses including *Cynodon dactylon* and *Sporobolus virginicus* (Russell-Smith 1995). These species are cosmopolitan in distribution, generally occurring throughout much of coastal Australia.

This wetland type is also represented within the Ramsar site by saline/semi-saline communities that overlie saline muds on the seaward side of floodplains, adjacent to tidal creeks or tidally inundated salt flats, in shallow water that is 20 centimetres deep or less (Cowie *et al.* 2000). These brackish swamp communities are characterised by grass species such as *Leptochloa fusca, Paspalum vaginatum, Sporobolus virginicus* and *Xerochloa imberbis*.

Figure 2-7 Intertidal marshes and saltpans along South Alligator River (source: BMT WBM)

Type I: Intertidal forested wetlands

Within the Ramsar site, intertidal forested wetlands are represented by mangrove communities (Figure 2-8). Extensive mangrove forests extend along the coastal shoreline as well as tidal reaches of rivers and streams, becoming increasingly more fragmented inland and along smaller creeks (refer Figure 2-9, also see Finlayson and Woodroffe 1996). In particular, mangrove communities fringing the Wildman, West Alligator and South Alligator Rivers are prominent. Approximately 8689 hectares of mangroves are present within the Ramsar site (mapping provided by Parks Australia), noting that these areas may have changed in the time period elapsed since the mapping was done (1989). It should be also noted that mangrove forests on Barron and Field Islands are not mapped by Parks Australia (Figure 2-9), but are known to be well developed at these two locations (Figure 2-2).

Mangrove communities in the Kakadu National Park region are floristically diverse, with thirty-eight mangrove tree and shrub species identified (Wightman 1989). Many of these species are widespread in coastal Australia and throughout Indo-Malaysia (Duke 1992). Species composition of mangrove communities is in zoned bands that run parallel to the shoreline in accordance with species tolerances to environmental conditions. In the coastal region, grey mangrove *Avicennia marina* is typically on the landward side, a central band is composed of spider mangrove *Rhizophora stylosa* and a seaward distribution of white mangrove *Sonneratia alba* (Davie 1985), while *Sonneratia lanceolata* occurs upstream (Finlayson *et al.* 1988).

Mangrove communities are highly productive and provide important habitat for fauna species. These include birds, fisheries resources including invertebrates and fish (for example, barramundi) and traditional foods. Furthermore, mangrove communities are notable as they have an important function in coastal stabilisation through protection against coastal erosion, they create a buffer against extreme weather events, and they have a role in sediment trapping and consequently contribute to the quality of coastal waters.

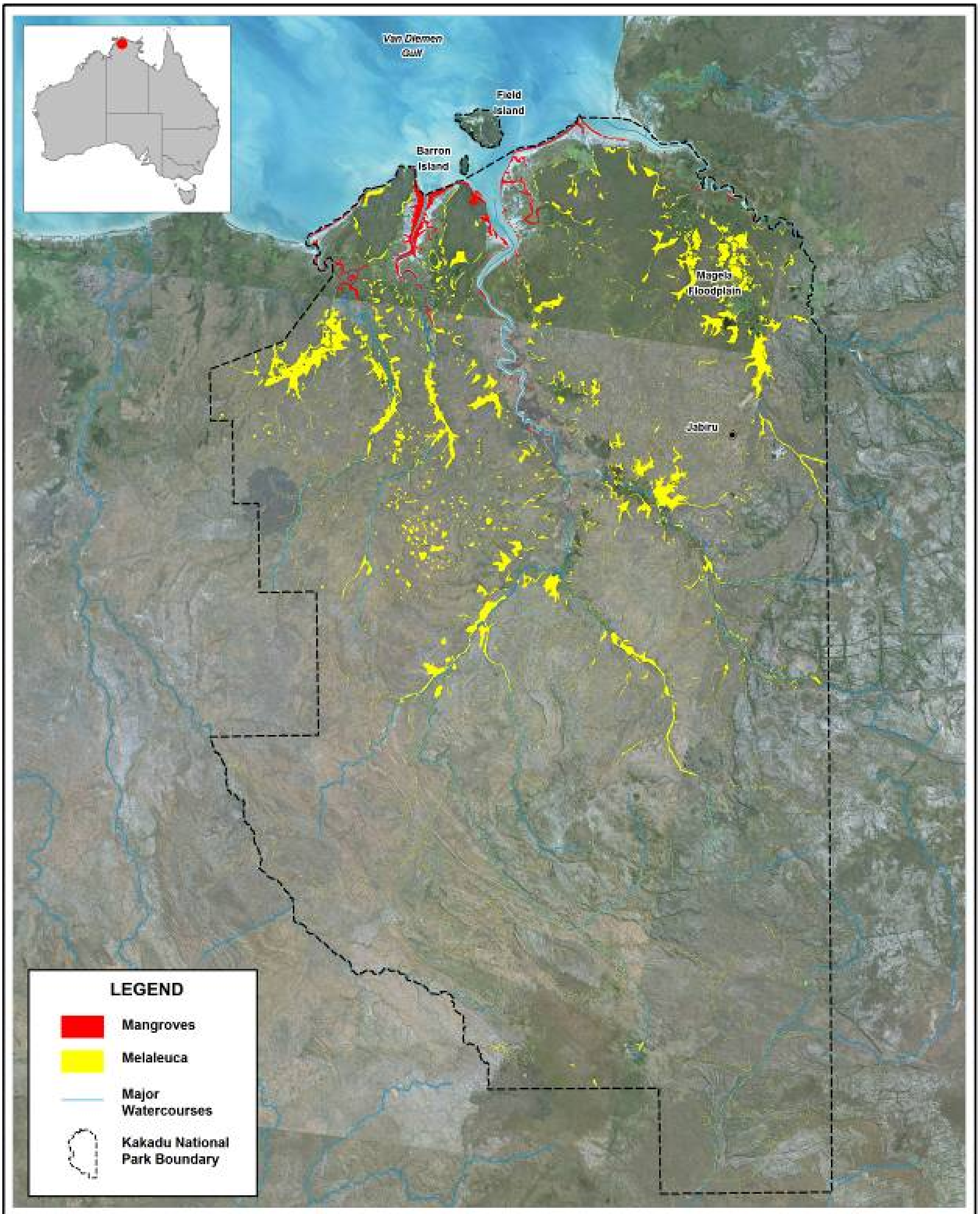
Figure 2-8 Mangroves along the South Alligator River (source: BMT WBM)

Type J: Coastal brackish/saline lagoons

This habitat type includes brackish to saline lagoons with at least one relatively narrow connection to the sea. Although not listed in the 1998 RIS for either of the historic (pre-merger) Ramsar sites, a saline lagoon is present at the northern tip of Field Island. The broader distribution of coastal saline lagoons within the Ramsar site is unknown.

Type K: Coastal freshwater lagoons

This wetland type consists of coastal freshwater lagoons. Although not listed in the 1998 RIS for either of the historic (pre-merger) Ramsar sites, chenier ridges at Pococks and Middle Beaches reportedly contain freshwater lagoons (Buck Salau, Parks Australia pers.comm).



Title:

Mangroves and Melaleuca forests within the Ramsar Site

Figure: 2-9

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N 0 20 40km Approx. Scale

BMT WBM www.bmtwbm.com.au

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2.4.2 Inland Wetland Types Present

Type L: Permanent inland deltas

A permanent inland delta is present at Yellow Water.

Figure 2-10 Yellow Water – an example of a permanent lake and inland delta (source: BMT WBM)

Type M: Permanent rivers/streams/creeks

This wetland type incorporates permanent rivers, streams and creeks, including waterfalls. Representative examples of this wetland type include Coirwong, Barramundi, Jim Jim and Nourlangie Creeks, and Wildman, East Alligator, West Alligator and South Alligator Rivers (Figure 2-11). It is also possible, but not confirmed, that parts of Katherine and Mary Rivers and their tributaries contain this wetland type.

The riparian vegetation communities that line rivers and streams are highly variable depending on the type of river and influences of seasonality (Petty *et al.* 2008). Common riparian species include weeping paperbark *Melaleuca leucadendra,* silver-leaved paperbark *M. argentea,* cajeput *M. cajuputi,* river pandanus *Pandanus aquaticus,* river red gum *Eucalyptus camaldulensis,* freshwater mangrove *Barringtonia acutangula,* river she-oak *Casuarina cunninghamiana,* weeping tea-tree *Leptospermum longifolium,* black wattle *Acacia auriculiformis,* northern swamp mahogany *Lophostemon grandiflorus* and *L. lactifluus* (Brock 1993). A large proportion of riparian flora species are also common to monsoon forests (see Wetland Type Y) (for example, Leichhardt tree *Nauclea orientalis, Syzygium* *armstrongii,* white apple *S. forte,* cluster fig *Ficus racemosa, Xanthostemon eucalyptoides*), with the margins of these habitats often intergrading (Brock 1993).

Extensive sandbanks may be associated with permanent and seasonal watercourses, and are important for turtle and crocodile nesting.

Figure 2-11 Permanent river wetland type within South Alligator River (source: BMT WBM)

Type N: Seasonal rivers/streams/creeks

This wetland type incorporates seasonal (i.e. ephemeral) rivers, streams and creeks, and is represented within the Ramsar site by seasonal drainings that commence flowing with monsoonal rains marking the start of the wet season. Flow of these seasonal streams and creeks declines and eventually stops in the dry season. Seasonal streams are widespread in the upper reaches of all catchments. Riparian vegetation communities associated with seasonal rivers and streams have been described for Type M above. Additionally, waterfalls occur on the edge of the sandstone plateau, with well-known examples including Jim Jim Falls and Twin Falls (both of which contain permanent water although flows are not perennial).

Type O: Permanent Freshwater Lakes

This wetland type includes permanent freshwater lakes that are larger than eight hectares in area. Although not listed in the 1998 RIS for either historic (pre-merger) site, this wetland type is represented within the Ramsar site by permanent freshwater billabongs that exceed the eight hectares area threshold (as digitised for part of the Ramsar site by BMT WBM 2010, refer Figure 2-15). With regards to the figure, note that billabong digitisation was only done for a portion of the site, and that only billabongs greater than eight hectares are classified as Type O.

Representative examples of billabongs include Chirracarwoo Lagoon (approximately 101 hectares), Leichhardt Billabong (approximately 17 hectares), Billabong (approximately 32 hectares) and Yellow Water.

Mixed community herblands comprised of submerged, floating and emergent plant species are associated with permanent freshwater billabongs. These communities are often dominated by waterlilies such as white snowflake lily *Nymphoides indica* and the traditional food species red lily *Nelumbo nucifera*, with other macrophyte species including *Limnophila australis, Triglochin dubium* and *Caldesia oligococca* (Finlayson 2005). Billabongs provide dry season refuges for many of the aquatic fauna species.

Type Tp: Permanent freshwater marshes/pools

This wetland type includes ponds less than eight hectares in area, as well as marshes and swamps on inorganic soils with emergent vegetation that is waterlogged for at least most of the growing season. Within the Ramsar site, it is represented by permanent freshwater billabongs that are smaller than the eight hectares area threshold, such as Couramoul Waterhole (approximately three hectares) (refer Figure 2-9). With regards to this figure, note that billabong digitisation was only done for a portion of the site, and that only billabongs less than eight hectares are classified as Type Tp.

Additionally, this wetland type incorporates sedge and grass-dominated marshes on the wettest parts of the floodplains that are inundated for most or all of the year (Cowie *et al.* 2000). These marshes are widespread throughout the floodplain of all catchments within the site.

Type Ts: Seasonal/intermittent freshwater marshes/pools

This wetland type is composed of seasonal/intermittent freshwater marshes and pools on inorganic soils, including seasonally flooded meadows and sedge marshes (Figure 2-12). This wetland type is represented within the Ramsar site by vast tracts of freshwater wetlands that comprise the seasonally inundated floodplains. While vegetation is sparsely distributed during the dry season, floodplain wetlands are covered with one to two per metres of water and a multitude of plants during the wet season (Finlayson and Woodroffe 1996).

The floodplain wetlands are primarily sedge- and/or grass-dominated meadows that form complex spatial mosaics. Flora species comprising the floodplain wetlands are predominantly cosmopolitan in distribution (Taylor and Dunlop 1985), with characteristic species including wild rice *Oryza* spp., spike-rush *Eleocharis* spp), native hymenachne *Hymenachne acutigluma* and water couch *Pseudoraphis spinescens* (Russell-Smith 1995, Finlayson 2005). Commonly encountered waterlilies include blue waterlily *Nymphaea violaceae*, yellow snowflake lily *Nymphoides hydrocharoides* and white snowflake lily *Nymphoides indica*.

The outstanding value of freshwater floodplains to fauna is well-recognised, particularly with regards to waterbirds that congregate in large numbers.

Figure 2-12 Seasonally inundated floodplain at Mamukala. (source: BMT WBM)

Type Xf: Freshwater tree-dominated wetlands

This wetland type includes freshwater swamp forests, seasonally flooded forests and wooded swamps on inorganic soils (Figure 2-13). Although not listed in the 1998 RIS for either site, this wetland type is represented within the Ramsar site by swamp forests occurring along billabong and stream margins that are inundated by up to one metre of water during the wet season (Finlayson 2005).

Large areas of *Melaleuca* swamp forest occur within the site, such as at Marndoki, Big Swamp and Boggy Plain (refer to Figure 2-9). Mapping by Brocklehurst and van Kerckhof (1994) shows that 74 113 hectares of *Melaleuca* is mapped in the Ramsar site, noting that these areas may have changed in the 15 years since the mapping was done.

Dominant species include broad-leafed paperbark *Melaleuca viridiflora, Melaleuca cajuputi* and white paperbark *Melaleuca leucadendra*, with other tree species commonly encountered including freshwater mangrove *Barringtonia acutangula* and screw pine *Pandanus spiralis* (Finlayson 2005).

Melaleuca forests are noteworthy in terms of the structural complexity that they add to the floodplain. In particular, *Melaleuca* forests offer roosting and nesting sites for birds such as magpie geese, green pygmy geese, cormorants and darters. Additionally, *Melaleuca* forests provide seasonal food resources such as nectar for birds (for example, honeyeaters and lorikeets) during the wet season.

Melaleuca forests within the Ramsar site are highly productive and contribute a large amount of material to the detrital/debris turnover cycle on the floodplain (Finlayson *et al.* 1993).

Figure 2-13 *Melaleuca* swamp forest at East Alligator River (source: BMT WBM)

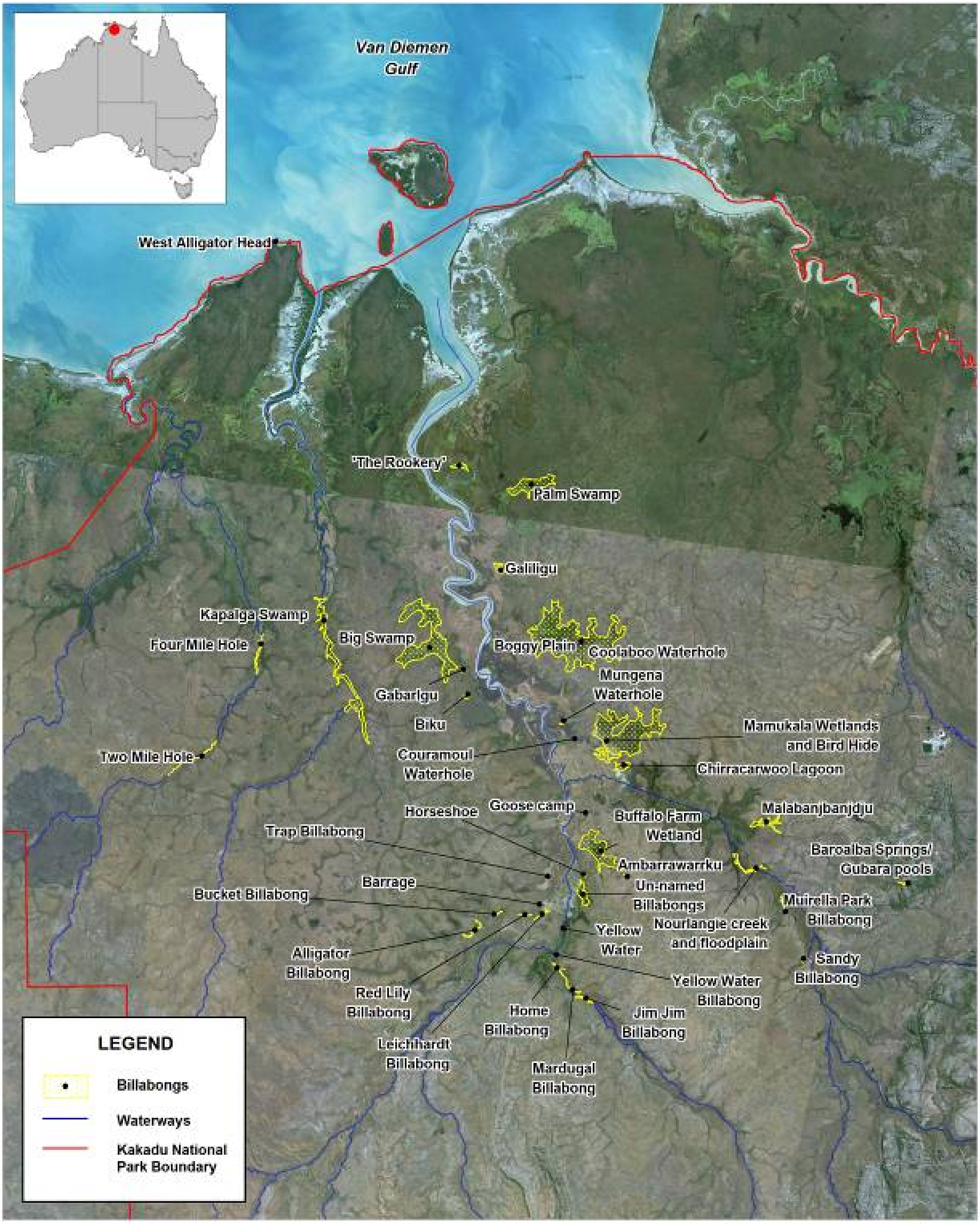
Type Y: Freshwater Springs

Although not listed in the 1998 RIS for either site, freshwater springs (Figure 2-14) are present within the Ramsar site. Some of these freshwater springs may support vegetation including screw pine *Pandanus* spp. communities or monsoon rainforest composed of ferns, palms and other tree species (for example, styptic tree *Canarium australianum* and banyan tree *Ficus virens*). Patches of monsoon rainforest are typically less than a few hectares in extent, but may occasionally form extensive tracts as riparian vegetation (Russell-Smith 1991). Permanent swamps on the floodplains may also be spring-fed, with paperbarks forming dense stands on these swamps (typically weeping paperbark *Melaleuca leucadendra,* cajeput *M. cajuputi* and broad-leaved paperbark *M. viridiflora*) (Brock 1993).

Vegetation mapping of monsoon forest has been provided by Parks Australia, and locations of a small number of freshwater springs within Kakadu National Park have been documented (by Buck Salau of Parks Australia, noting that some GPS points may be at a distance along the spring rather than at the source). These data have been overlaid to produce Figure 2-16. However, in interpreting this figure it is important to note that locations of all springs have not been recorded, and that not all patches of monsoon forest are supported by freshwater springs (monsoon forest can also be associated with creeks and other sites of year round water availability). Furthermore, monsoon forest supported by springs is not necessarily at the source of the spring, but can be located along the length (for example, Benbunga Spring and Coonbanrbora Spring).

A number of permanent seeps are also located within the escarpment, but no empirical data describing their locations are available.

Figure 2-14 Freshwater spring (source: Buck Salau, Parks Australia)



Title:

Billabongs within South Alligator River Catchment (source: BMT WBM 2009)

Figure: 2-15

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 10 20km

Approx. Scale

BMT WBM

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2.4.3 Discrepancies with the 1998 RISs

A number of differences exist between the 1998 RISs for the historic (pre-merger) Ramsar sites and the current study in terms of the identification of wetland types that are present. However, differences do not represent an actual change in wetland types over time but instead reflect (i) differences in the interpretation of wetland typology descriptions; and (ii) an increase in knowledge of wetland type distribution since the preparation of the 1998 RISs.

Summarised from above, the following wetland types that were previously not identified for Kakadu National Park site but are now known to be present include the following:

- Type D – Rocky marine shores
- Type J – Coastal brackish/saline lagoons
- Type K – Coastal freshwater lagoon
- Type O – Permanent freshwater lakes
- Type Xf – Freshwater tree dominated wetlands, and
- Type Y - Freshwater springs.

The following wetland types that were previously identified as present within the site are not considered to occur in the site.

Type A: Permanent shallow marine waters

This wetland type incorporates marine waters that are less than six metres deep at low tide, including sea bays and straits. However, only waters above low water are included within the Ramsar site boundaries, and subtidal waters within the river channels are classified as estuarine waters (Type F). Therefore, this wetland type is not considered to be present in the Ramsar site.

Type R: Seasonal/intermittent saline/brackish/alkaline lakes and flats

Seasonal saline lakes are not thought to be represented within the Kakadu National Park Ramsar site.

Type Sp: Permanent saline/brackish/alkaline marshes/pools

Permanent saline marshes within the Ramsar site are not considered to be inland, but are rather classified as coastal wetlands (Type H).

Type Xp: Forested peatlands

This wetland type incorporates peat swamp forests and forested peatlands are not represented within Kakadu National Park. It is likely that inclusion of Type Xp in the 1998 RISs was an error that should rather have been Type Xf (described above).

2.5 Nomination Criteria Met by the Site

2.5.1 Criteria Under which the Site was Designated

At the time that Kakadu National Park (Stage I and wetland components of Stage III) was extended and Kakadu National Park (Stage II) was first nominated as a Wetland of International Importance, there were 11 criteria against which a wetland site could qualify (Table 2-5). The different criteria which the two Kakadu Ramsar sites were considered meeting are shown in the table below.

Table 2-5 Criteria for identifying Wetlands of International Importance as at listing, as documented in 1989 and 1995 RISs

Basis	Number	Description	Kakadu National Park (Stage I and wetland components of Stage III) - 1995 RIS	Kakadu National Park (Stage II) -1989 RIS
Criteria for representative or unique wetlands	1a	it is a particularly good representative example of a natural or near-natural wetland, characteristic of the appropriate biogeographical region.	Met	Met
	1b*	it is a particularly good representative example of a natural or near-natural wetland, common to more than one biogeographical region.	Met	
	1c*	it is a particularly good representative example of a wetland, which plays a substantial hydrological, biological or ecological role in the natural functioning of a major river basin or coastal system, especially where it is located in a trans-border position.	Met	Met
	1d*	it is an example of a specific type of wetland, rare or unusual in the appropriate biogeographical region.		
General Criteria based on plants and animals	2a	it supports an appreciable assemblage of rare, vulnerable or endangered species or subspecies of plant or animal, or an appreciable number of individuals of any one or more of these species.	Met	Met
	2b	it is of special value for maintaining the genetic and ecological diversity of a region because of the quality and peculiarities of its flora and fauna.	Met	Met
	2c	it is of special value as the habitat of plants or animals at a critical stage of their biological cycle.	Met	Met
	2d	it is of special value for one or more endemic plant or animal species or communities.		Met
Specific criteria based on waterbirds	3a	it regularly supports 20 000 waterbirds	Met	Met
	3b*	it regularly supports substantial numbers of individuals from particular groups of waterbirds, indicative of wetland values, productivity or diversity.	Met	Met
	3c	where data on populations are available, it regularly supports one percent of the individuals in a population of one species or subspecies of waterbirds.	Met	

*Criteria not available in 1980 when Stage I was first nominated as a Wetland of International Importance, note that Criterion 1 in 1980 was considered a grouping of 1(a) and 1 (d).

The 1998 RIS assessed the site against the 13 criteria adopted at the 6th Conference of Contracting Parties in Brisbane in 1996, Table 2-6 summarises the criteria met by the two historic (pre-merger) Ramsar sites and those that are met by the current ECD.

Table 2-6 Summary of nomination criteria met by the two historic Kakadu National Park Ramsar sites as outlined in the 1998 RIS, and the current Kakadu National Park ECD

Criterion		Historic Kakadu National Park (Stage I and wetland components of Stage III)	Historic Kakadu National Park (Stage II)	Kakadu National Park
		1998 RIS	1998 RIS	Current ECD
Group A. Sites containing representative, rare or unique wetland types				
1	A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.	**Met as 1a** - *The floodplains are outstanding examples of their types in the monsoon tropics.* **Met as 1b** - *No justification provided.* **Met as 1c** - *The two river systems of the wetlands are outstanding examples of the series of large rivers of the Torresian monsoonal biogeographic region draining into the Arafura Sea. Together with the West Alligator and Wildman rivers in the adjoining wetland of Kakadu National Park Stage II they are the only such river systems under statutory conservation management.*	**Met as 1a** - *No justification provided*. **Met as 1c** - *The three river systems of the wetlands are outstanding examples of the series of large rivers of the Torresian monsoonal biogeographic region draining into the Arafura Sea. Together with the East Alligator and upper South Alligator rivers in the adjoining Stage 1 wetland they are the only such river systems under statutory conservation management.*	**Met**
Group B. Sites of international importance for conserving biological diversity				
2	A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.	**Met as 2a** - *The wetland is noted for or important to the conservation of the magpie goose, whistling tree duck, Burdekin duck, yellow chat, eastern grass owl, collared kingfisher, false water rat, goldenbacked tree rat, pig-nosed turtle, Mariana's hardyhead, exquisite rainbow fish, Midgley's grunter and the frog <u>Megistolotes lignarius.</u>*	Not met	**Met**
3	A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.	**Met as 2b** - *No justification provided.* **Met as 3b** - *Between August and October up to one million waterbirds accumulate on the floodplains, notably those of Nourlangie Creek. More than 60 species of waterfowl occur in the wetlands including large concentrations of magpie geese and wandering whistling duck.*	**Met as 2b** - *No justification provided.* **Met as 3b** - *Between August and October up to one million waterbirds accumulate on the floodplains, notably those of Magela Creek. More than 60 species of waterfowl occur in the wetlands including large concentrations of magpie geese and wandering whistling duck.*	**Met**
4	A wetland should be considered internationally important if it supports plant	**Met as 2c** - *Magpie geese, wandering whistling duck and many other species breed in the*	**Met as 2c** - *Magpie geese, wandering whistling duck and many other species breed in the*	**Met**

Criterion		Historic Kakadu National Park (Stage I and wetland components of Stage III)	Historic Kakadu National Park (Stage II)	Kakadu National Park
		1998 RIS	1998 RIS	Current ECD
	and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.	*wetlands but most species are dry season migrants. Thirty-five species of wader have been recorded, including many winter migrants to the sub-Arctic, whose first Australian landfall is the Kakadu National Park area. Fifty-nine fish species (excluding obligate marine species) are known from the wetland including eight with narrowly restricted ranges. Breeding populations of both freshwater and estuarine crocodiles occur.*	*wetlands but most species are dry season migrants. Thirty-five species of wader have been recorded, including many winter migrants to the sub-Arctic, whose first Australian landfall is the Kakadu National Park area. Fifty-nine fish species (excluding obligate marine species) are known from the wetland including 8 with narrowly restricted ranges. Breeding populations of both freshwater and estuarine crocodiles occur.*	
5	A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.	**Met as 3a** - *Between August and October up to one million waterbirds accumulate on the floodplains, notably those of Nourlangie Creek.*	**Met as 3a** - *Between August and October up to one million waterbirds accumulate on the floodplains, notably those of Magela Creek.*	**Met**
6	A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.	**Met as 3c** - *No justification provided.*	**Met as 3c** - *No justification provided.*	**Met**
7	A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.			**Met**
8	A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.			**Met**
9	A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.			**Met**

Italicised text is justification as stated in the 1998 RIS; blue shading indicates criteria did not exist at the time of the 1998 RIS

2.5.2 Assessment Based on Current Information and Ramsar Criteria

There have been a number of developments in the past decade that influence the application of the Ramsar criteria to wetland sites this includes:

- Refinements and revisions of the Ramsar criteria since 1996. An additional criterion was added at the 9th Ramsar Conference in Uganda in 2005.
- Revision of population estimates for waterbirds (Wetlands International 2006; Bamford *et al.* 2008), which influences the application of criterion six.
- A decision with respect to the appropriate bioregionalisation for aquatic systems in Australia, which for inland systems are now based on drainage divisions and for marine systems the interim marine classification and regionalisation for Australia (IMCRA). This affects the application of criteria one and three.
- Updating of threatened species listings, which affects criterion two.
- Additional data have been collected for the site, which could potentially influence the application of all criteria.

Therefore an assessment of the Kakadu National Park Ramsar site against the current nine Ramsar criteria has been undertaken. The Nomination Criteria have been reconsidered in this ECD, with specific reference to more up-to-date requirements outlined in “Handbook 14 Designating Ramsar Sites” (Ramsar Convention Secretariat 2007) and the National Framework (DEWHA 2008).

2.5.3 Criterion 1

A wetland should be considered internationally important if it contains a representative, rare, or unique example of a natural or near-natural wetland type found within the appropriate biogeographic region.

Criterion 1 (met at time of listing and continues to be met based on current assessment)

Criterion 1 considers habitat types and their representativeness within a given biogeographic region (bioregion). As outlined in Section 1.4.5, the site occurs in the Timor Sea Drainage Division and the Northern IMCRA Provincial Bioregion. The Timor Sea Drainage Division contains several major river systems which include (proceeding northward then eastward) the Fitzroy, Isdell, Prince Regent, Mitchell, Drysdale, King George, Ord, Victoria, Adelaide, Mary, West, South and East Alligator, Mann and Goyder Rivers. Of these, the Ord, Victoria Daly and Fitzroy Rivers are the largest by area and flow volumes (CSIRO 2009).

As discussed in Section 2.4, the wetland types occurring within the site are representative of landscape and wetland types found in the Northern IMCRA Provincial Bioregion and the Timor Sea Drainage Division. The 1998 RISs note that:

- The floodplains are outstanding examples of their types in the monsoon tropics (Stage I/III and II).
- The three river systems are outstanding examples of the series of large rivers of region (Stage I/III and II), and are the only rivers under statutory conservation management within the region.

Of particular noteworthiness, the Kakadu National Park Ramsar site incorporates all major ‘Top End’ habitat types within a single drainage basin – the South Alligator River (Director of National Parks 2007). There are no particularly unique or rare wetland types within the site, and the range of landscape and wetland habitat types are found in other catchments within the bioregion (for example, Mary River, Adelaide River).

Unlike more developed areas of Australia, most catchments, rivers and estuaries in the Timor Sea drainage division, including those within the Kakadu National Park Ramsar site, are considered in a natural or near-natural condition (National Land and Water Resources Audit 2002; see Figure 2-17). Unlike other catchments within the bioregion, the Ramsar site and most of the catchment area of constituent wetlands are situated within a National Park, and are therefore subject to limited direct development pressure. Floodplain wetlands have also largely recovered from past disturbance by water buffalo (see Section 5.2), although areas of moderate degradation occur in places as a result of impacts of weeds and feral animals (Figure 2-17). Mining has also resulted in disturbance to the landscape although the extent of disturbance is relatively small (see Section 5.5).

The fundamental processes that control wetland functioning, notably fluvial hydrology, tidal hydraulics and water quality processes remain in natural condition (see Section 3.5). Fire regimes, which are a key control of flora and fauna communities and populations in non-tidal areas, are actively managed within the Kakadu National Park (see Section 3.5.2). Furthermore, there is a major management program for weeds and feral animals within Kakadu National Park, but this is unmatched elsewhere in the bioregion.

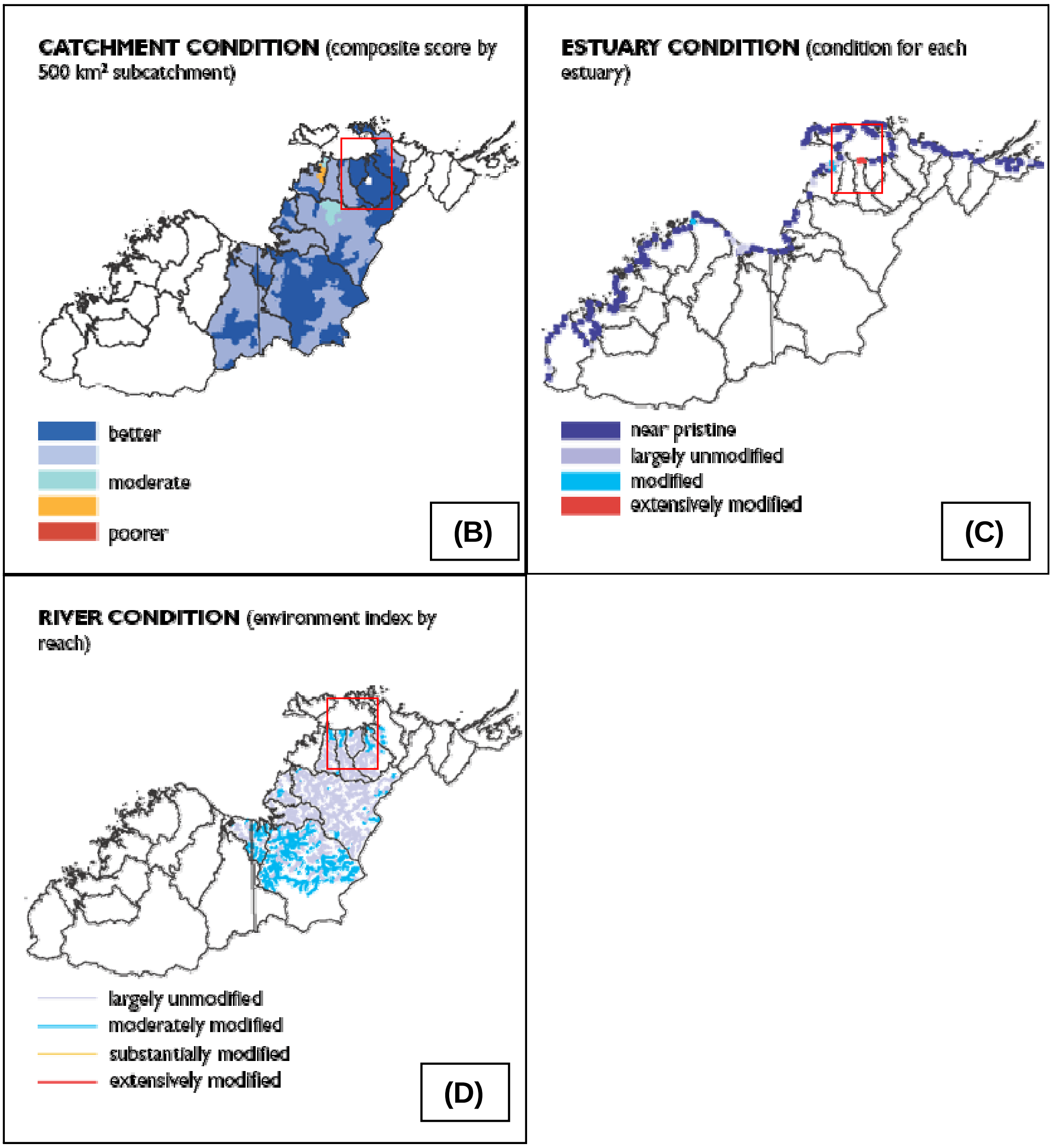


Figure 2-17 (B) Catchment condition (C) estuary condition and (D) river condition at a bioregional scale. Red rectangle indicates location of the Kakadu Ramsar site. (source: NLWRA 2002)

For these reasons, the site is considered to be excellent representative examples of wetlands in the bioregion and which are in natural or near-natural condition.

An outline of the justification for how the site meets this Criterion is provided in Table 2-7 below. Noteworthy features that provide justification for this Criterion include the vast areal coverage of relatively intact floodplain habitats and Field Island contains representation examples of all of the coastal wetland types known to occur within the Ramsar site, with the exception of coastal freshwater lagoons. This represents a remarkably high level of habitat diversity within a relatively small area.

Table 2-7 Justification for criterion 1

Ramsar Handbook Element	Justification
Representative, rare, unique wetland type in natural/near-natural condition	• All wetland types are in natural/near-natural condition and are representative of wetland types found in the Northern IMCRA Provincial Bioregion and within the Timor Sea Drainage Division. • No unique or rare wetland types known to occur within the site.
Substantial role in natural functioning of a major river basin or coastal system	• The site contains almost the complete catchment of the South Alligator and Wildman drainage basins, which in the case of South Alligator, represents one of the largest river systems in the drainage division.
Hydrological importance:	• The vast floodplain systems provide dry season water retention for floodplain wetlands. • The vast floodplain systems represent a major natural floodplain system.

2.5.4 Criterion 2

A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

Criterion 2 (met at time of listing and continues to be met based on current assessment)

The ECD Framework (DEWHA 2008) indicates that 'wetland' flora and fauna species should be considered in the context of this Criterion. This has been interpreted here as 'wetland-dependent' species, and therefore does not include terrestrial species that are not reliant on aquatic/wetland habitats (see Appendix C for complete species lists as well as a list of wetland-dependent vertebrate fauna). It is also possible that threatened aquatic invertebrate species also occur with the site (for example, species of dragonfly, see Clausnitzer *et al.* 2009), however these are either not listed as nationally or internationally threatened, or there are no published records of these species within the site.

No internationally or nationally threatened wetland-dependent flora species are known to occur within the Kakadu National Park Ramsar site. There are nine internationally or nationally threatened wetland-dependent fauna species known to occur within the site as outlined in Table 2-8. Further information on these species has been provided in Section 3.7.1 in the context of the threatened species critical service.

Note that the Australian painted snipe *Rostratula australis*, listed as vulnerable under the EPBC Act, is not included above as there are no verified records within the site, though it is acknowledged that areas of potentially suitable habitat occur within the site and this cryptic species may occur within either site. Franklin (2008) lists 34 records of the Australian painted snipe within the northern tropical rivers catchments (a study area which includes Kakadu National Park), and found that records were concentrated in drier parts of the northern catchments.

The water mouse *Xeromys myoides* is listed as vulnerable under the EPBC Act and by the IUCN. There is a single record from Kakadu National Park in 1903, though no further evidence of the water mouse occurrence has been confirmed, despite recent targeted surveys in potentially suitable habitat (for example, intertidal mangrove wetlands and adjacent salt marsh and sedgeland) (S. Ward pers. comm. 2009). As a result, this species has not been included in the context of meeting the Criterion.

Table 2-8 Threatened wetland-dependent species

Species	Common name	Status	Habitats	Site Usage
Semi-aquatic terrestrial Fauna				
Epthianura crocea tunneyi	yellow chat (Alligator Rivers)	EPBC - E	Saltmarsh/palustrine wetland.	Major population present on-site (e.g. Woinarski and Armstrong 2006).
Carettochelys insculpta	pig-nosed turtle	IUCN - V	Floodplain billabongs.	Major population present on-site (e.g. Georges and Kennett 1989).
Marine Megafauna				
Glyphis garricki sp. nov. (formerly *Glyphis* sp. C)	northern river shark	EPBC – E IUCN – E	Relatively shallow, upper freshwater to brackish (0-26 ppt) river reaches (TSSC 2001a).	Recorded in West, East and South Alligator Rivers (Larson 2000).
Glyphis glyphis (formerly *Glyphis* sp. A)	speartooth shark	EPBC – CE IUCN - E	Freshwater and brackish areas of rivers (0.8 to 28 ppt) (Pillans *et al.* 2005; Pogonoski and Pollard 2003).	Populations known to occur in East and South Alligator Rivers (Compagno *et al.* 2008).
Natator depressus	flatback turtle	EPBC –V IUCN – DD	Nesting on open coastline (sand beaches). Feeds in turbid coastal waters, mostly on benthic fauna.	Field Island is an important nesting area (Schäuble *et al.* 2006), forming part of one of six major nesting sites in Australia.
Pristis clavata	dwarf sawfish	EPBC –V	Turbid rivers and coasts	Record from South Alligator River (Larson *et al.* 2006a).
Pristis microdon	freshwater sawfish	EPBC –V IUCN – CE	Typically found in turbid channels of large rivers over soft mud bottoms (Allen 1991) > 1 m deep.	Recorded in Kakadu National Park (Larson *et al.* 2006) however population status unknown.
Chelonia mydas	green turtle	EPBC –V IUCN – E	Feeds on seagrass and mangroves.	Recorded at the site (Winderlich 1998 cited in Schäuble *et al.* 2006) but not thought to represent a key area.
Dugong dugon	dugong	IUCN - V	Feeds on seagrass (particularly *Halophila* and *Halodule*).	Extensive seagrass beds at Field Island are dugong feeding areas (Roelofs *et al.* 2005).

Blue shading – while the species occurs on the site, it is not thought that the site provides a particularly important habitat for this species.

Status under the EPBC Act and IUCN Red List where CE = critically endangered, E = endangered, V = vulnerable, DD = data deficient.

2.5.5 Criterion 3

A wetland should be considered internationally important if it supports populations of plant and/or animal species important for maintaining the biological diversity of a particular biogeographic region.

The site meet Criterion 3 for most elements outlined in Section 70 of the *Ramsar Handbook for Wise Use of Wetlands 14* (Ramsar Convention Secretariat 2007), namely:

Section 70 (i) High biodiversity

A range of endemic species occur at the site (see below), automatically qualifying the site as supporting high biodiversity. In addition, the site also supports a diverse assemblage of flora and fauna species, including:

- Nearly 1600 plant species (Director of National Parks 2007).
- Sixty-one mammal species, including four species regarded as wetland-dependent (Appendix C).
- One hundred and five reptile species, including 20 species regarded as wetland-dependent (Appendix C).
- Twenty-six frog species (all wetland-dependent species) (Appendix C).
- Two hundred and sixty-seven bird species, comprising 91 waterbird species (including 28 migratory and nine resident shorebird species, and 10 gull and tern species) and 11 bird species (other than waterbirds) which regarded as wetland-dependent (Appendix C).
- Fifty-nine fish species (Bishop *et al.* 2001; see Appendix C), which represents over half of the total freshwater fish fauna of the Timor Sea bioregion (Allen *et al*. 2002) (refer Section 2.5.9).

Species lists for terrestrial vertebrate fauna recorded within the site (as well as wetland-dependent vertebrate fauna) are provided in Appendix C.

Section 70 (ii). Centres of endemism or contains significant numbers of endemic species

Wetland flora within the Ramsar site is largely comprised of wide-ranging, non-endemic species, with only four species present that are restricted to the drainage division - *Bambusa arnhemica, Hygrochloa aquatica, Nymphoides spongiosa* and *N. subacuta* (Cowie *et al.* 2000).

The ancient stone country contains significant endemic aquatic invertebrate components, including:

- Endemic family of shrimps (Kakaducarididae), containing two mono-specific genera (*Leptopalaemon* and *Kakaducaris*) (Bruce 1993, Page *et al.* 2008).
- Endemic genus of isopod (*Eophreatoicus*) that has exceptional species diversity (approximately 30 species, Wilson *et al.* 2009).
- A high proportion of mayfly species from the family Leptophlebiidae is endemic to the bioregion. Specifically, seven of the nine species found in Kakadu National Park are endemic to the Timor Sea Drainage Division (Finlayson *et al.* 2006), with one of these species thought to be restricted to a single stream within the Ramsar site (Dean and Suter 2004).

Kakadu National Park contains a significant portion of the total geographic range of four freshwater fish species that are restricted to the drainage division (Allen *et al.* 2002). These species are exquisite rainbowfish *Melanotaenia exquisita*, Magela hardyhead *Craterocephalus marianae* (also known as Mariana's hardyhead), sharp-nosed grunter *Syncomistes butleri* and Midgley's grunter *Pingalla midgleyi*.

Section 70 (iii) Contain the range of biological diversity (including habitat types) occurring within a region.

In terms of species, the site contains the range of tree and shrub mangrove species for the bioregion (38 species).

In terms of habitat types, the current study identifies that almost all Ramsar Wetland types known to occur within the bioregion are represented within the site. Specifically, nine of the 12 Ramsar marine/coastal wetland types occur within the Kakadu National Park Ramsar site (refer Section 2.4.1), noting however that all marine/coastal wetland types are represented within the Timor Sea Drainage Division. The current study also identifies that eight of the 20 inland/freshwater Ramsar wetland habitat types are supported in the site (refer Section 2.4.2), noting that at least four of the inland wetland types absent from the site do not occur within the bioregion (Types U, Va, Vt and Zg).

Table 2-9 Ramsar nomination criterion 3

Wetland feature	Description
High biodiversity	• A wide range of plant and animal species.
Centres for endemism	• Four flora species endemic to the drainage division. • Shrimp family endemic to drainage division. • Isopod genus endemic to drainage division. • Seven mayfly species endemic to drainage division. • Four fish species endemic to the drainage division.
Contain range of diversity of the bioregion	• The site contains the range of tree and shrub mangrove diversity for the bioregion.
Contain range of habitat types known from bioregion	• All but three coastal/marine Ramsar wetland types. • Eight of the twenty inland Ramsar wetland types.
Significant proportion of species adapted to special environmental conditions	Most floodplain-associated species have life-cycle characteristics that allow them to persist in seasonally flooded floodplain environments.
Elements of biodiversity that are rare or particularly characteristic of bioregion	N/A

2.5.6 Criterion 4

A wetland should be considered internationally important if it supports plant and/or animal species at a critical stage in their life cycles, or provides refuge during adverse conditions.

Based on Ramsar Convention Secretariat (2007), there are two elements that need to be considered for this criterion:

1. Section 74. Whether the site has high proportions of the population of **mobile or migratory** species gathered in small areas at particular stages of their life-cycle, and

2. Section 75. For **non-migratory species**, whether the site supports habitats for species that are unable to evade unfavourable climatic or other conditions (that is the site contains critical refugia areas).

In the context of Section 74 of Ramsar Convention Secretariat (2007), the following are relevant in addressing this Criterion:

- Breeding habitat for significant waterbird aggregations. The most significant breeding colonies are located within mangal communities of the major rivers, and floodplain-associated freshwater marshes. Examples include:
  - Colony near mouth of South Alligator River – Multi-species colony with an estimated colony size of up to 5000 waterbirds (Chatto 2000).
  - Colony within mangroves adjacent to and east of South Alligator River, approximately 15 kilometres from the South Alligator River mouth. This is a large multi-species colony (exceeding 13 000 birds per annum in some years) that is dominated by egrets. Eight waterbird species have been confirmed to breed here (Chatto 2000).
  - Colony within mangroves along the southern banks of the East Alligator River and extending up a tributary approximately 15 kilometres in from river mouth. Ten waterbird species have been confirmed to breed here, with the highest estimated annual usage exceeding 11 500 birds (Chatto 2000).
  - Significant breeding aggregations of magpie geese *Anseranas semipalmata* throughout the floodplains of the site (up to 27 percent of the Northern Territory breeding population), with the South Alligator floodplains regarded as the third most important area of nesting habitat after the Mary-Adelaide and Daly River floodplains (Bayliss and Yeomans 1990).
- Feeding and roosting habitat for:
  - Thirty-nine shorebird species (including 29 non-breeding migratory species), which collectively occur in significant numbers. The site is identified as being internationally important for migratory shorebirds in the East Asian-Australasian Flyway (Bamford *et al.* 2008).
  - Fifty-three waterbird species (other than shorebirds), which collectively occur in significant numbers (see data for Criterion 5).
- In the context of Section 75 in Ramsar Convention Secretariat (2007), the following are relevant in addressing this Criterion:

- Dry season refuge for large concentrations of waterbirds as a result of the persistence of freshwaters on the Magela and Nourlangie floodplains and several back swamps of the South Alligator River (for example, Boggy Plain) (Morton *et al.* 1990b). During the late dry season, waterbird abundance is likely to exceed a million birds (Morton *et. al*. 1991). Notable records include a maximum monthly dry season mean abundance (1981 to 1984) of 545 000 birds from nine waterbird species (Morton *et al.* 1993b) and approximately 600 000 birds from five duck species (Morton *et al.* 1990b). Such large aggregations appear to be unique in Australia (Morton *et al.* 1990b).
- Feeding, refuge and breeding habitats for terrestrial vertebrate fauna species (other than waterbirds) regarded as wetland-dependent. These include:
  - Three mammal species: northern myotis *Myotis moluccarum*, mangrove pipistrelle *Pipistrellus westralis*, and water-rat *Hydromys chrysogaster*.
  - A wide variety of reptiles are known to depend on aquatic or semi-aquatic habitats of the site during the dry season (Shine 1986a,b, Sadlier 1990, Friend and Cellier 1990, Braithwaite *et al.* 1991, Woinarski and Gambold 1992, Finlayson *et al.* 2006). This includes freshwater crocodile *Crocodylus johnstoni*, saltwater crocodile *Crocodylus porosus*, pig-nosed turtle *Carrettochelys insculpta*, *Chelodina burrungandjii*, northern long-necked turtle *Chelodina rugosa*, northern snapping turtle *Elseya dentata*, *Elseya jukesi*, saw-shelled turtle *Elseya latisternum*, northern red-faced turtle *Emydura victoriae*, mangrove monitor *Varanus indicus*, Merten’s water monitor *Varanus mertensi*, Mitchell’s water monitor *Varanus mitchellii*, water python *Liasis fuscus*, Arafura file snake *Acrochordus arafurae*, little file snake *Acrochordus granulatus*, bockadam *Ceberus rynchops*, Macleay’s water snake *Enhydris polyepis*, white-bellied mangrove snake *Fordonia leucobalia*, Richardson's mangrove snake *Myron richardsonii* and keelback *Tropidonophis mairii*.
  - Twenty-six frog species have been recorded on the site (for example, Tyler *et al.* 1983, Tyler and Cappo 1983, Tyler and Crook 1987, Woinarski and Gambold 1992, Finlayson *et al.* 2006, see Appendix C).
  - Twelve bird species (other than waterbirds): osprey *Pandion haliaetus*, white-bellied sea-eagle *Haliaeetus leucogaster*, brahminy kite *Haliastur indus*, azure kingfisher *Alcedo azurea*, little kingfisher *Alcedo pusilla*, collared kingfisher *Todiramphus chloris*, yellow chat *Epthianura crocea tunneyi*, mangrove robin *Eopsaltria pulverulenta*, white-breasted whistler *Pachycephala lanioides*, mangrove golden whistler *Pachycephala melanura*, shining flycatcher *Myiagra alecto*, and mangrove grey fantail *Rhipidura phasiana* (see Appendix C).

The permanent billabongs and river channel environments provide dry season refugia for these semi-aquatic wetland-dependent species, as well as purely aquatic species such as fish, and many aquatic invertebrates and macrophyte species. It should be noted however that these same refugia functions would also take place in other permanent waterbodies in wetlands throughout the bioregion. It is uncertain how critical the Ramsar site is in terms of maintaining viable populations of most of the non-migratory/non-mobile species. The possible exceptions to this are threatened and/or endemic species, such as:

- Endemic invertebrate species found in the stone country (see section 2.5.3). Note however that the specific watering requirements of these species are unknown.
- The regionally endemic exquisite rainbowfish *Melanotaenia exquisita*, which is restricted to perennial pools at Jim Jim Creek within the Park (see section 2.6.2).
- The perennial river systems of the site which support two threatened shark species, two threatened sawfish species and pig-nosed turtle (see Section 2.5.2).

2.5.7 Criterion 5

A wetland should be considered internationally important if it regularly supports 20 000 or more waterbirds.

The findings of various studies indicate that the site regularly supports in excess of 20 000 or more waterbirds on an annual basis (Bayliss and Yeomans 1990, Bamford 1990, Morton *et al.* 1991, Chatto 2000, Chatto 2003a, Chatto 2006, see Appendix C). Peaks in abundance occur immediately prior to and after the wettest months of the year (January–March). During these peak periods, the waterbird population within floodplain areas of the site has been estimated to contain almost one million birds, with densities of up to 100 birds per hectare recorded during the late dry season (Morton *et al*. 1991). The total waterbird population for the Alligator Rivers Region during the late dry season is likely to be in excess of 2.5 million birds (Morton *et al.* 1993b). Notable records of waterbird abundance are outlined below:

- The highest estimated annual usage of the five largest breeding colonies collectively amount to greater than 40 500 birds (Chatto 2000).
- In excess of 172 000 waterbirds were counted within the upstream South Alligator River floodplains during October 2001 (Chatto 2006). Approximately 23 000 birds were recorded within the downstream floodplains and approximately 49 000 birds were recorded within the upstream floodplains of the East Alligator River in October 2001 (Chatto 2006).
- The highest monthly mean for the dry season is 545 000 birds from nine waterbird species and approximately 600 000 birds from five duck species across five floodplains in the Alligator Rivers Region: Magela, Nourlangie, East Alligator River floodplains (upstream and downstream), and Boggy Plain (Morton *et al.* 1990a and 1993b).
- Bamford (1990) recorded nearly 69 000 waterbirds during ground counts on a limited number of floodplain billabongs in October to November 1987.
- Chatto (2003a) recorded large aggregations of shorebirds from Finke Bay (9000 birds in 1993) and in coastal areas between the South Alligator River and Minimini Creek (12 500 birds in 1992).
- For a single species alone, namely magpie goose *Anseranas semipalmata*, population estimates exceeded 300 000 birds in each of the five years surveyed (1983-1986) with the highest estimate during the 1984 dry season (2 539 802 ± 1 372 568) and lowest estimate during the 1986 wet season (517 998 ± 210 353) (Bayliss and Yeomans 1990). Morton *et al.* (1990a) estimated that the Alligator Rivers Region (that is, Magela, Nourlangie, East Alligator, Cooper and South

Alligator (Boggy Plain) floodplains) supports an average of about 1.6 million geese in the dry season, though considerably less during the wet season (November to March).

2.5.8 Criterion 6

A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of waterbird.

The following waterbird species have been recorded within Kakadu National Park in numbers which exceed one percent of the estimated population size (Wetlands International 2006):

- Magpie goose *Anseranas semipalmata* - The one percent population threshold for this species is 20 000 birds (Wetlands International 2006). Significant counts include:
    - Annual population counts in excess of 300 000 birds and estimates of greater than 1.6 million geese in the dry season (see Section 2.5.5).
    - Highest estimated number of nests in the years 1984 to 1986 was 45 200 ± 9403 (1985), with the lowest being 24 446 ± 5373 (1986) (Bayliss and Yeomans 1990).
    - Bamford (1990) recorded 32 154 magpie geese during surveys in October to November 1987.
- Wandering whistling-duck *Dendrocygna arcuata* - The one percent population threshold for this species is 10 000 birds (Wetlands International 2006). Peak abundance (highest monthly mean for period 1981-1984) for the flood plains of the Alligator Rivers Region was estimated to be 400 000 birds (Morton *et al.*1990b).
- Plumed whistling-duck *Dendrocygna eytoni* - The one percent population threshold for this species is 10 000 birds (Wetlands International 2006). Peak abundance (highest monthly mean for period 1981-1984) for the flood plains of the Alligator Rivers Region was estimated to be 70 000 birds (Morton *et al.*1990b).
- Radjah shelduck *Tadorna radjah* – A one percent population threshold has not been calculated for this species (Wetlands International 2006), though the following comments provide a guide – Garnett and Crowley (2000) estimate an Australian population of 100 000 breeding adults (150 000 individuals), though population may be smaller (Wetlands International 2006). In assuming the upper estimate, counts recorded for the site would exceed any conservative estimate of a one percent population threshold. Morton *et al.* (1990b) estimated peak abundance (highest monthly mean for period 1981-1984) for the flood plains of the Alligator Rivers Region to be 30 000 birds.
- Pacific black duck *Anas superciliosa* - The one percent population threshold for this species is 10 000 birds (Wetlands International 2006). Peak abundance (highest monthly mean for period 1981-1984) for the flood plains of the Alligator Rivers Region was estimated to be 50 000 birds (Morton *et al.*1990b).
- Grey teal *Anas gracilis* - The one percent population threshold for this species is 20 000 birds (Wetlands International 2006). Peak abundance (highest monthly mean for period 1981-1984) for

the flood plains of the Alligator Rivers Region was estimated to be 50 000 birds (Morton *et al.*1990b).

- Brolga *Grus rubicunda* - The one percent population threshold for this species is 1000 birds (Wetlands International 2006). Peak abundance (highest monthly mean for period 1981-1984) for the flood plains of the Alligator Rivers Region was estimated to be 24 000 birds (Morton *et al.*1993a).

- Black-necked stork *Ephippiorhynchus asiaticus* - The one percent population threshold for this species is 300 birds (Wetlands International 2006). Aerial counts (which in comparison to ground surveys are known to under-estimate numbers) undertaken monthly between 1981 and 1984 demonstrated that estimated average numbers on the floodplains of Alligator Rivers exceeded the one percent threshold for five of the 12 counts (Morton *et al.*1993a). From both ground and aerial counts, a measure of the maximum regional population was estimated to be about 1800 birds (Morton *et al.*1993a).

The following migratory shorebird species have been recorded within Kakadu National Park in numbers which exceed one percent of the estimated population size in the East Asian – Australasian Flyway (Bamford *et al.* 2008):

- Marsh sandpiper *Tringa stagnatilis* – Bamford *et al.* (2008) estimates that the one percent population threshold for the flyway is 1000 birds. Site records include 1600 birds (Chatto 2003a).
- Little curlew *Numenius minutus* - The current flyway one percent threshold is 1800 (Bamford *et al.* 2008). Site records include 180 000 birds (Morton *et al.* 1990). Morton *et al.* (1991) reported approximately 300 000 little curlew passing through the wetlands in Kakadu National Park during October in the early 1980's, and Bamford (1990) reported 50 000 little curlew in Kakadu National Park in the late dry seasons of 1987, 1988 and 1989 (with a single day count from six day roosts of 17 380 birds (11 November 1987) and 10 000 birds from a single roost on Boggy Plains (19 October 1987).
- Common sandpiper *Actitis hypoleucos* - The current flyway one percent threshold is 250 (Bamford *et al.* 2008). Site records include 300 birds (Bamford 1988).
- Australian pratincole *Stiltia isabella* - The current flyway one percent threshold is 600 (Bamford *et al.* 2008). Site records include 30 000 birds (Morton *et al.* 1991) and 1391 birds (Bamford 1990).
- Sharp-tailed sandpiper *Calidris acuminata* - The current flyway one percent threshold is 1600 (Bamford *et al.* 2008). Site records include 4900 birds (Chatto 2003a) and 3000 birds (Chatto 2003a).

Chatto (2003a) indicates that other species may occur in numbers which exceed the threshold (terek sandpiper *Xenus cinereus*, broad-billed sandpiper *Limicola falcinellus*, grey plover *Pluvialis squatarola,* and lesser sand plover *Charadrius mongolus*) though suitable data to confirm this view are not currently available.

2.5.9 Criterion 7

A wetland should be considered internationally important if it supports a significant proportion of indigenous fish subspecies, species or families, life-history stages, species interactions and/or *populations that are representative of wetland benefits and/or values and thereby contributes to global biological diversity.*

From a species richness perspective, the freshwater fish fauna of the site is reportedly high on a national scale. To date, 59 freshwater fish species (that is, species that have an obligatory freshwater stage) have been recorded in the site (Bishop *et al*. 2001; see Appendix C). This represents approximately 20 percent of the total number of fish species found in Australian freshwaters (302 species) and 60 percent of the freshwater fish recorded from the Timor Sea Drainage Division (approximately 100 species) (Allen *et al.* 2002, CSIRO 2009), and is the highest species richness of any catchment in the bioregion (Burrows 2008). However, Burrows (2008) also notes that this is also by far the most intensively sampled region of northern Australia, both spatially and temporally. Additionally, Burrows (2008) derived species richness values for sampling locations throughout the bioregion based on past surveys, but noted that differences in sampling methods and effort preclude direct comparisons of these data (refer Section 3.3.6).

Allen *et al.* (2002) notes that the Magela Creek catchment alone is species-rich compared to catchments on other continents, and despite its small size, has as many or more species than the extensive Murray-Darling system in south east Australia.

Five species have been recorded only from the northern part of the Northern Territory (exquisite rainbowfish *Melanotaenia exquisita*, Magela hardyhead *Craterocephalus marianae*, sharp-nosed grunter *Syncomistes butleri*, Midgley's grunter *Pingalla midgleyi* and a potential new species of *Hypseleotris* gudgeon), and Kakadu National Park contains a significant portion of the total range of the first four of these species. Ramsar Convention Secretariat (2007) also considers endemism as an important element of biodiversity, and the four fish species listed above are endemic to the drainage division (refer Section 2.5.5).

There are insufficient data to determine the proportion of marine/estuarine fish (or shellfish) species that the Ramsar site support relative to the total fish diversity in the bioregion.

Ramsar Convention Secretariat (2007) also emphasises that the term diversity can encompass a number of life-history stages, species interactions and complexity of fish-environmental interactions. The fish assemblages of the site is comprised of species with different life-history characteristics, including potadromous (entirely freshwater) species, to diadromous (requiring marine and freshwaters to complete life-cycle) and fully marine species. The site also supports a wide variety of life history stages for many species (i.e. eggs, larvae, recruitment sites, spawning sites).

2.5.10 Criterion 8

A wetland should be considered internationally important if it is an important source of food for fishes, spawning ground, nursery and/or migration path on which fish stocks, either within the wetland or elsewhere, depend.

Kakadu National Park provides important habitats, feeding areas, dispersal and migratory pathways, and spawning sites for numerous fish species of direct and indirect fisheries significance. These fish have important fisheries resource values both within and external to the Ramsar site.

No commercial fishing is allowed within the site. However, recreational angling is a key use of the site. The recreational fishery is based almost entirely on one species: barramundi *Lates calcarifer*, although other non-target species are also captured. From a cultural perspective, barramundi represents a key traditional food species and has other cultural values (for example, totem – see Section 3.7.3; 3.8.4).

While commercial fishing does not occur within the site, many commercially significant species occur within Kakadu National Park that may be harvested elsewhere. Many fish (for example, barramundi, threadfin salmon, mullet species) and crustacean (mud crabs, prawns) species spend their juvenile stages in shallow nearshore waters of the site, particularly around mangroves, saltmarsh and seagrass habitats. Species such as barramundi also inhabit freshwater floodplain and billabongs. These species also spawn in inshore waters, although there is no information on specific spawning habitats within the site (See Section 3.3.6).

Note that Section 3.7.2 (Service 3) provides a more detailed account of fish habitat values of the site.

2.5.11 Criterion 9

A wetland should be considered internationally important if it regularly supports one percent of the individuals in a population of one species or subspecies of wetland-dependent non-avian animal species.

Criterion 9 relates to non-avian wetland taxa including, *inter alia*, mammals, reptiles, amphibians, fish and aquatic macroinvertebrates. In interpreting the application of Criterion 9 to these species, Ramsar Convention Secretariat (2007) indicates that reliable population size limits from published sources must be included in the justification for the application of this Criterion.

The following species meet this Criterion:

- Northern river shark *Glyphis garricki* sp. nov – This species occurs in scattered localities in coastal New Guinea and Australia, with specific Australian locations known to be King Sound and Doctors Creek in Western Australia, and the Adelaide, West, East and South Alligator Rivers in the Northern Territory (Compagno *et al.* 2008). It is inferred that the total population size of this species is estimated to be 250 mature individuals (see Ward and Larson 2006a). Based on this, the one percent population threshold is three individuals, and therefore this species is considered to exceed the one percent population threshold as it is known from three localities within the Ramsar site.
- Speartooth shark *Glyphis glyphis* – This species occurs in scattered localities in northern Australia, with specific locations known to be the Bizant and Wenlock Rivers in Queensland and the Adelaide, East Alligator and South Alligator Rivers in the Northern Territory, as well as near Port Romilly in New Guinea (Compagno *et al*. 2008). It is inferred that the total population size of this species is estimated to be 250 mature individuals (see Ward and Larson 2006b). Therefore, the one percent population threshold is exceeded within the Ramsar site.
- Pig-nosed turtle *Carettochelys insculpta* – This species occurs in New Guinea and northern Australia. Within Australia, substantial breeding populations of pig-nosed turtles are known to occur in four major river drainages in the Northern Territory, namely, the East Alligator, South Alligator, Daly and Victoria Rivers (TSSC 2005), with reliable anecdotal reports also including the Victoria, Fitsmaurice and Goomadeer systems (Doody *et al.* 2000). As the Australian pig-nosed turtle population is completely isolated from the New Guinean populations (Cogger and Heathcote 1981), the one percent population threshold is calculated based on only the Australian

numbers of individuals. Population surveys estimate that the Australian population is approximately 3000 individuals (R. Sims pers. comm. to TSSC 2005), and the one percent threshold is therefore 30 individuals. Georges and Kennett (1989) found pig-nosed turtles to be widespread between the tidal reaches and the head-waters of the South Alligator River, and that high densities may be present in the upper reaches during the dry season (33.8 ± 11.3 turtles per hectare in small discrete ponds on the main channel). Based on this information, the one percent population threshold is exceeded within the Ramsar site.

- Saltwater crocodile *Crocodylus porosus* – Although saltwater crocodiles have historically had a wide distribution throughout southeast Asia and Australasia, the species is currently thought to be extinct throughout most of Asia. Isolated, relatively small populations are known to remain in Myanmar (Burma), eastern India, Indonesia, Malaysia, Philippines and the Solomon Islands. The vast majority of the global population of saltwater crocodiles occurs in northern Australia, and they are also common in New Guinea. In Australia, the saltwater crocodile population has been thriving since the species was protected from hunting, particularly in the Northern Territory, which has the largest population and densities in Australia (Fukuda *et al.* 2007), and population size is estimated as 60 000 individuals (NTG not dated), but may actually be far greater than this number (Simon Ward pers. commo. 2010). Within the Northern Territory, Kakadu National Park (Alligators Rivers Region) contains the largest protected area of suitable habitat (approximately 19 120 km^2) (Leach *et al.* 2009) and it is estimated that the site contains approximately 15 000 saltwater crocodiles (S. Ward pers. comm. 2009), therefore exceeding the one percent population threshold.

It is likely that the freshwater crocodile *Crocodylus johnstoni* also meets this Criterion; however, sufficient data are not available at the site scale to determine whether the Criterion is met for this species. Freshwater crocodiles are endemic to northern Australia, occurring in Western Australia, Northern Territory and Queensland. Considering their distribution and that the site contains a significant proportion of the suitable habitat within this distribution, it is likely that the site support at least one percent of the population. Should adequate data become available, then this species will be included in this Criterion.

The endemic invertebrate species that appear to be restricted to seeps in the escarpment country are also likely to exceed this threshold. However, as there are no published accurate estimates of population numbers of these species, under Ramsar Handbook 14 guidelines (Ramsar Convention Secretariat 2007) these species cannot contribute to this criterion. It is noted that there has been comparatively less collection effort in other areas outside the site than has occurred in Kakadu National Park. Investigation of survey data for other regionally endemic species as part of the current study has shown such data are largely incomplete and forms an information gap.

3 CRITICAL COMPONENTS, PROCESSES AND SERVICES/BENEFITS

3.1 Study Approach

3.1.1 Background

This Section outlines the critical components, processes and services/benefits that make up the ecological character of the Kakadu National Park Ramsar site.

The method employed to identify critical components, processes and services/benefits is presented in Appendix B. Following the method within the National Framework (2008), the assignment of a given wetland component, process or service/benefit as critical was guided by the following considerations:

- the component, process or service/benefit is an important determinant of the uniqueness of the site, or is widely accepted as representing a particularly outstanding example of an environmental value supported by the site,
- the component, process or service/benefit is important for supporting one or more of the Ramsar Nomination Criteria under which the site was listed, and
- a change to the component, process or service/benefit would result in a fundamental change in ecological character of the site.

Additionally, a second tier of 'supporting' components, processes and services/benefits have been identified. These 'supporting' components, processes and services/benefits, while important to wetland functioning, were in isolation were not considered to directly address the criteria listed above (see Appendix B).

For each of the critical components, processes and services/benefits (C, P, S/B), a brief description is provided for (i) the rationale for inclusion as a critical; (ii) a description of the element and (iii) a description of patterns in variability over time. It should be noted that in nearly all cases, there was no actual baseline data-set describing the wetland indicator before or at the time of declaration of the sites (Stage I = 1980; Stage II = 1989; Stage III = 1995). Therefore, in the following sections, both pre-listing and post-listing data have been used to describe patterns in variability in space or over time. The specific years in which the data was collected is noted in the following sections, together with a description of whether the numerical values are likely to representative of conditions at the time of listing.

3.1.2 Environmental Values Identified by the Fox Review

As discussed above, in assessing whether a particular component, process or service/benefit (C, P, S/B) is critical, there is a need to consider (among other factors) any elements that have been identified as having particularly outstanding environmental values. Environmental values may be documented in nomination criteria for the declaration of Ramsar or national park sites. The '*Commission of Inquiry in respect of all environmental aspects for and in relation to the development by the Australian Atomic Energy Commission in association with Ranger Uranium Mines Pty Ltd or* *uranium deposits in the Northern Territory*' prepared by Fox *et al.* (1977) included an extensive review of Kakadu National Park's natural and cultural values. The Fox report was crucial to supporting the gazettal of Kakadu as a National Park and listing under the World Heritage Convention and Ramsar Convention shortly thereafter. Therefore, the Fox *et al*. (1977) report was used as a basis for identifying critical components, process and services/benefits that are important with respect to determining the site's unique character with respect to the Framework (as per second bullet point above).

In particular, the critical components and services/benefits nominated by this ECD were selected so as to strongly correlate with the 'qualities of the area favouring establishment of a national park' as listed in Fox *et al.* (1977) as follows:

1. *The region has a wide variety of landscape, vegetation and wildlife types which are not to be found elsewhere on the continent.*

2. *The important land type features which are well represented in the Alligator Rivers Region are the Arnhem Land plateau, the escarpment and outliers, the floodplains, the permanent lagoons and swamps and the major tidal river systems.*

3. *Biological features that are of importance are:*

    a. *A wide range of aquatic and terrestrial vegetation types.*

    b. *An abundance and considerable diversity of plant and animals species including birds and fishes.*

    c. *The occurrence of relic communities and species such as rainforests and semi-deciduous forests, some birds, insects, fishes and one species of turtle.*

    d. *The occurrence of rare species well represented in the region and some endemic races and perhaps species and certainly many new records of species.*

4. *Attractive scenic features including notably, vegetation communities associated with various landscape features and the concentration of aquatic birds that occur in the swamp lands during the dry season.*

5. *The region has an abundance of Aboriginal relics and features especially Aboriginal art of which there is no equivalent elsewhere in Australia.*

6. *It provides scope for scientific study in many disciplines including geology, geomorphology, botany, zoology, ecology, limnology, archaeology and Aboriginal culture.*

7. *It presents a variety of opportunities for organised and unorganised recreational and educational activities such as sightseeing and lecture tours, bird and animal watching, natural history study, swimming, bush walking, photography, and wilderness exploration for those experienced and qualified in this kind of activity in such a region and climate.*

8. *The foregoing features exist in a close to natural state, in a very diversified but relatively compact region.*

9. *Although individual sites may have limited capacity at any one time, a representative national park in the regional could collectively serve a large number of visitors with varying interests providing it was comprehensively organised and specifically managed for the purpose.*

3.2 Overview of Critical Services, Components and Processes

A summary of the critical and supporting wetland components, processes and services/benefits for the Kakadu National Park Ramsar site as determined in the present study is shown in Table 3-1. In summary, the following have been identified:

- eleven critical components and six supporting components
- four critical processes and five supporting processes, and
- three critical services/benefits and five supporting services/benefits.

The broad interaction of wetland components, processes and services/benefits (both critical and supporting) at a whole-of-site level is shown in Figure 3-1. The figure shows three broad processes (climate, geomorphology and regional-scale hydrodynamic and hydrological processes) that together have shaped the topography, marine and freshwater flow regime and other important aspects of the site. At the local habitat scale, there is a mix of physical and chemical processes as well as biological processes that control the wetland habitats and associated biota. The interaction of the wetland components with the wetland processes yields a range of wetland services/benefits that are characterised as biodiversity (ecosystem services) and cultural services (relevant to providing a social or economic benefit to humans) using the terminology in the National Framework and Millennium Ecosystem Assessment.

The following sections provide a more detailed description of critical components, processes and services for Kakadu National Park that form the basis of this ECD. Where possible, information on the different original listing and extension dates (1980,1989,1995 and 2010) has been identified to aid in the description of natural variability for the components, processes and services at the time of listing.

Table 3-1 Summary of critical and supporting components, processes and services/benefits

	Components	Processes	Services/Benefits
Critical	C1 – Mangroves C2 – *Melaleuca* Forests C3 – Palustrine Wetlands and Billabongs C4 – Waterfalls, Seeps and Waterholes C5 – Populations of Migratory and Resident Waterbirds C6 – Populations of Freshwater Fish C7 – Populations of Freshwater and Saltwater Crocodiles C8 – Populations of Threatened Sharks C9 – Yellow Chat Populations C10 – Pig-nosed Turtle Populations C11 – Locally Endemic Invertebrate Species	P1 – Fluvial Hydrology P2 - Fire Regimes P3 – Breeding of Waterbirds P4 – Flatback Turtle Nesting	S1 – Maintenance of Global Biodiversity S2 – Fisheries Resource Values S3 – Contemporary Living Culture
Supporting	Seagrass Monsoon Rainforests and Riparian Vegetation Other Wetland Habitats Terrestrial Habitats Aquatic Invertebrates Regionally Endemic Species	Climate Geology/Geomorphology Tidal Hydraulics Groundwater Water Quality Ecosystem Processes	Recreation and Tourism Scientific Research and Education Historical Cultural Heritage Biological Products Sites/Items of Cultural Significance

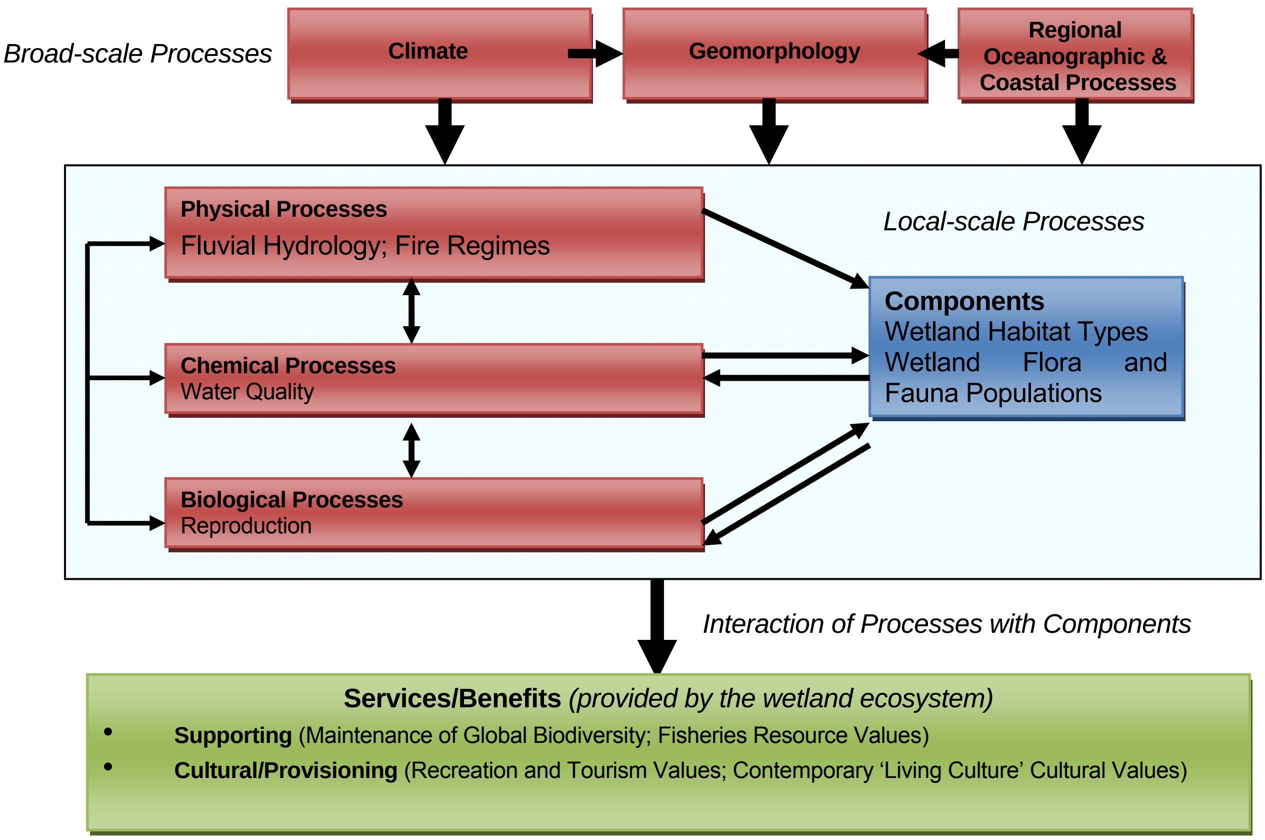


Figure 3-1 Conceptual model showing interactions between critical and supporting components, processes and services/benefits within the Ramsar site

3.3 Critical Components

As outlined in Section 2.4, a range of wetland habitat types are known to be present within the Ramsar site boundary, including a diversity of those designated within the coastal/marine and inland wetland categories under the Ramsar classification scheme. Within these habitat types, a rich diversity of wildlife exists from all the major groups of organisms (from planktonic organisms to vertebrates) which make up the ecosystem components of the wetland. Critical components of the site have been selected on the basis of those habitats, key species and wildlife populations that are fundamental in determining the site's ecological character and underpin the critical services/benefits, and are described below.

3.3.1 C1 – Mangroves

Reasons for Selection as 'Critical'

Mangroves were selected as a critical component due to the essential role that these communities have in terms of provisioning for species of fisheries value (Service 2). Furthermore, mangrove communities are important with respect to habitat provisioning for waterbird breeding colonies, and therefore, in turn, mangrove communities are fundamental to determining the site's ecological character, contribute to support of Ramsar Nomination Criteria 4, 5 and 6, and provide opportunities for recreation and tourism.

Description

Refer to Wetland Type I in Section 2.4.1.

Patterns in Variability

There are two data sources describing patterns in mangrove extent: Mitchell *et al.* (2007) and Cobb *et al*. (2007).

Mitchell *et al.* (2007) provides the most detailed mangrove mapping within Kakadu National Park (refer Table 3-2). The assessment was undertaken based on 1990 aerial photography, which is close to baseline pre-listing conditions in Stage II (1989), and includes the estuarine portions of Wildman, West and most of South Alligator Rivers, as well as Field and Barron Islands. The estuarine portions of East Alligator River are almost entirely within Stage I, which was declared in 1980, and therefore these data describe mangrove extent post-Ramsar site listing.

Table 3-2 shows that West and South Alligator Rivers had the largest mangrove areas. Tree height, as a relative measure of tree age, varied inconsistently between locations and broad geomorphological zones within locations (inland, coast and creek). Mitchell *et al.* (2007) concluded that the patterns in tree height are related to contemporary changes in erosion and sedimentation patterns.

Cobb *et al.* (2007) examined changes in mangrove area over time within Kakadu National Park. Note that this assessment was based on a review of remote imagery that did not involve ground-truthing, and was based on different mapping methods to those used by Mitchell *et al.* (2007). Mangroves extent was mapped for 1950 and 1975 (pre-listing for the site), 1985 (pre-listing for Stage II, post-listing Stage I) and 1992 (post-listing for both sites).

Table 3-2 Mangrove area and canopy height mapped from 1990 aerial photography (source: Mitchell *et al.* 2007)

Location	Listing date	Mangrove area (ha)	Tree height range (metre)		
			Inland	Coast	Creek
West Alligator	Stage II - 1989	3204	6 (edge) 20 (central)	10-16	14
South Alligator	Stage II - 1989	2673	6-12	10-16	9-15
Wildman	Stage II - 1989	960	8	7-13 (19 mouth)	6-7
East Alligator	Stage I - 1980	688 (coast)	10-14 (10 inland)	6-8	10-16
Field Island	Stage II - 1989	1712	8-18	5 (fringe); 18 (shore)	8-14
Barron Island	Stage II - 1989	70	8	7	-

Blue shading – data collected post listing and unlikely to reflect conditions at time of listing

Cobb *et al.* (2007) demonstrated that there was a long-term trend of mangrove expansion within the site between at least 1950 and 1991 (refer Figure 3-2). Figure 3-2 shows that the rate of change varies between catchments, as well as between time periods (Cobb *et al.* 2007).

The highest rate of change occurred at West and South Alligator Rivers (Stage II – 1989 declaration), particularly after 1975. Between 1984 and 1991 mangroves increased by 13 and nine square kilometres at South and West Alligator, respectively, whereas a three to four square kilometres increase was recorded at Wildman and West Alligator Rivers. While recognising that the 1991 data-set describes conditions just after listing, for the purposes of this study, these patterns in variability between 1950-1991 are assumed to represent baseline, pre-listing conditions for Stage II estuarine waterways.

In terms of Stage I estuarine waterways (East Alligator River), pre-listing mangrove extents were mapped on two occasions: 1950 and 1975. Between these two periods, mangrove extent increased from nine to 9.5 square kilometres. Note that by 1991 (11 years post-listing), mangrove extent had increased to 15 square kilometres.

Figure 3-2 also shows that the rates of change in mangrove extent varied among catchments. Between 1950 and 1991 the annual rate of increase in mangrove extent ranged from 0.12 square kilometres per year (Wildman), to 0.43 square kilometres per year (West Alligator), and 0.49 square kilometres per year (South and West Alligator Rivers). The highest rate of mangrove increase was between 1984 and 1991 at South Alligator River (2.1 km^2 per year), West Alligator River (1.5 km^2 per year), East Alligator River (0.6 km^2 per year) and Wildman (0.42 km^2 per year).

With respect to mangroves, it is evident that there is an inherent difficulty with quantifying 'natural variability' when the overall trend or trajectory is operating over a longer timescale than that assessed during the measurement period.

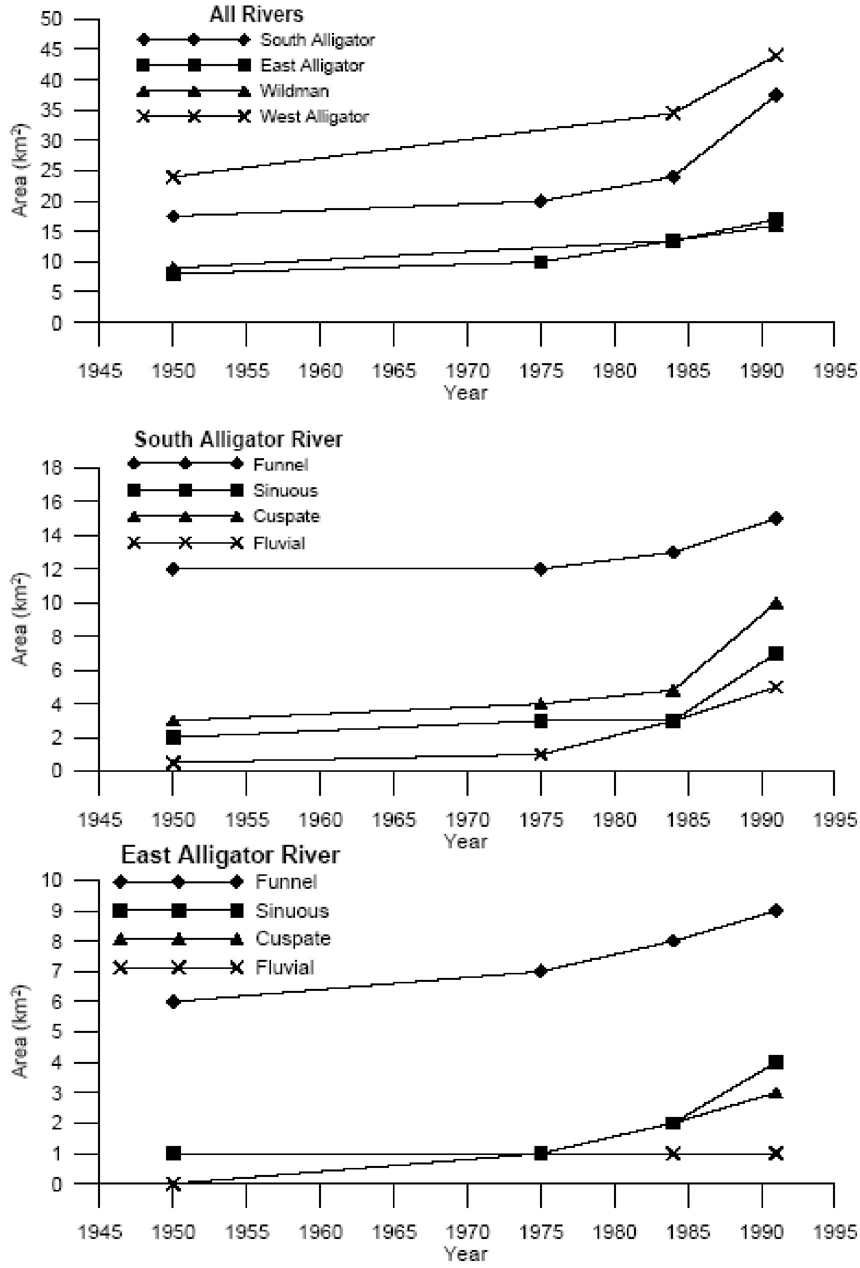


Figure 3-2 Area of mangroves mapped from 1950 to 1991 aerial photographs (source: Cobb *et al.* 2007)

Note: 'funnel' refers to the estuarine funnel at the river mouth, 'cuspate' refers to cuspate meanders, 'sinuous' refers to sinuous meanders and 'fluvial' refers to the main channel of the river.

3.3.2 C2 - *Melaleuca* Forests

Reason for Selection as 'Critical'

In a study that identified qualities of the Alligator Rivers Region that favoured National Park establishment, one of the recognised qualities was vegetation communities associated with various landscape features and the concentration of aquatic birds that occur in the swamp lands during the dry season (refer Fox *et al.* 1977). *Melaleuca* forests fit the description of these vegetation communities, and as such were selected as a critical component.

Description

Refer Wetland Type Xf in Section 2.4.2.

Patterns in Variability

Melaleuca forest can display natural variation in the extent of areas covered as well as the density of the forest. Due to the longevity of *Melaleuca* individuals, natural variability of *Melaleuca* forest communities is typically not detected over short timescales, with the exception of sudden dieback events that result from certain unexpected changes in environmental conditions. Specifically, saltwater intrusion is one of the principal factors contributing to the loss of *Melaleuca* communities within the Ramsar site. In contrast to this, concern has also been expressed regarding possible encroachment of *Melaleuca* forests over long timescales into areas of the Ramsar site that were previously not occupied by *Melaleuca* (for example, see Riley and Lowry 2002).

As discussed in section 2.4.2, Brocklehurst and van Kerckhof (1994) mapped *Melaleuca* forest extent in Kakadu National Park in 1992, which describes post-listing conditions for Stage I and II, and pre-listing condition for Stage III. This was a one-off study, and therefore, there are no empirical data describing natural variability in *Melaleuca* forest over time at the whole-of-site scale. However, a number of studies have examined changes in *Melaleuca* extent on localised scales, as described below.

Winn *et al.* (2006) used aerial photography interpretation to examine changes in *Melaleuca* extent (and morphological change – see section 3.2.3) at the mouth of the East Alligator River (Stage I) between 1950 and 1997[1]. Between 1950 and 1975 (pre-listing), dramatic increases in tidal creek expansion (and associated saltwater intrusion) occurred, resulting in a 45 percent reduction in *Melaleuca* forest extent. Around the time of listing, a further 26 percent reduction in *Melaleuca* extent occurred between 1975 and 1984, and a further seven percent reduction occurred between 1985 and 1997. Similar to temporal trends in mangrove extent (and intertidal flat extent; see Winn *et al.* 2006), it is apparent that there has been a long-term trend of increased salt water intrusion into freshwater wetlands (and associated changes in vegetation communities), which has been evident for at least 30 years prior to Ramsar site listing. These changes represent part of the ecological character of the Ramsar site.

There has been a large body of research describing changes in *Melaleuca* density and/or extent in the Magela floodplain, which is predominantly within Stage II (1989 listing). Two studies examined

[1] Note that the only empirical data presented by Winn *et a*l. (2006) were percentage change values.

changes in *Melaleuca* forests prior to Stage II listing: Williams (1984) examined *Melaleuca* densities, and Staben (2008) examined *Melaleuca* extent. Williams (1984) reported an overall decline in the density of *Melaleuca* on the Magela floodplain between 1950 and 1975.

Staben (2008) mapped *Melaleuca* extent on the Magela floodplains during four time periods: 1950, 1975, 1996 and 2004 (Figure 3-3). In contrast to the observed reduction in *Melaleuca* densities documented by Williams (1984), Staben (2008) observed an increase in *Melaleuca* extent between 1950 (118.9 hectares) and 1975 (133.4 hectares) time periods. Between 1975 and 1995 (i.e. six years after listing of Stage II), *Melaleuca* extent remained almost static (three hectare increase), but declined in 120.4 hectares by 2004. Staben (2008) suggested that differences in the results of these two studies could relate to differences in mapping methodologies and/or sampling (classification) errors in either of the studies.

Two other studies undertaken in the Magela floodplain describe changes in *Melaleuca* forests between a pre-listing sampling episode (either 1975 or 1983) and one post-listing sampling episode (1996, 2006). Riley and Lowry (2002) observed a net decline in the number of trees between 1975 and 1996 in the study area as a whole, as well as within four out of five sub-areas that together comprised the study area (refer Table 3-3). Similarly, Boyden *et al.* (2008) examined changes in the percentage cover of *Melaleuca* on the Magela floodplain between 1983 and 2003, and found a ten percent decrease in cover (refer Figure 3-4). These two studies are consistent with the findings of all other studies undertaken on the Magela floodplain except Staben (2008).

A number of processes could ultimately control these temporal patterns. Williams (1984) suggested that factors such as late dry-season fires, strong winds, buffalo and in some instances saltwater intrusion may be responsible for the decline in *Melaleuca* trees prior to listing. Other authors also highlight the potential impacts of fire, feral pigs, changes in rainfall patterns and successional changes due to sediment accumulation. This suggests that both natural and anthropogenic factors could have resulted in the observed changes to wetland communities in the period prior to listing.

Table 3-3 Number of *Melaleuca* trees on the Magela Floodplain (source: Riley and Lowry 2002)

Year	Sub-area 2	Sub-area 3	Sub-area 4	Sub-area 6	Sub-area 7	Total
1975	1886	2545	11 238	5447	10 317	31 433
1996	819	1404	6989	1797	13 695	24 704
Change	1067	-1141	-4249	-3650	+3378	-6729

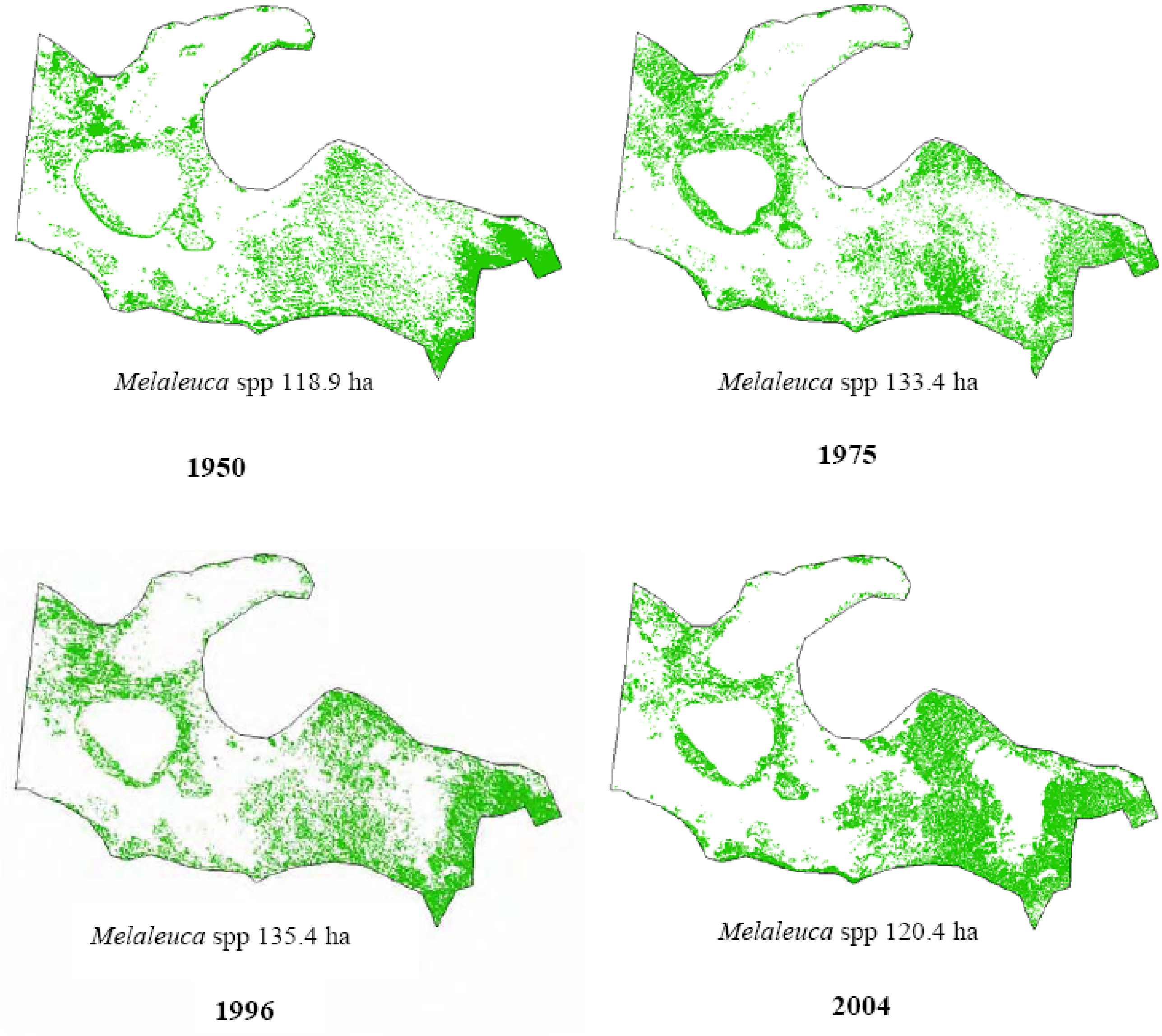


Figure 3-3 Spatial extent of *Melaleuca* cover (green shading) on the Magela floodplain for four time periods (source: Staben 2008)

3.3.3 C3 – Palustrine Wetlands and Billabongs

Reasons for Selection as 'Critical'

Fox *et al*. (1977) considered these habitats as important land type features that are well-represented within the Alligator Rivers Region, and therefore these habitats contributed significantly to proposals for declaration as a National Park. Furthermore, palustrine wetlands and billabongs were selected as a critical component as they are fundamental to determining the site's ecological character.

Specifically, billabongs provide areas of deep water habitat for aquatic flora and fauna, as well as dry season refuge for many of the aquatic fauna species that inhabit the floodplains. These fauna species include a diversity of freshwater fish (Criterion 7), a large number of waterbirds (Criteria 5 and 6), certain threatened species (for example, pig-nosed turtles – Criterion 2 and 9) and a number of traditional food species (for example, file snakes, freshwater turtles – see Section 3.8.4). Additionally, many traditional dietary staple plant species are associated with billabongs (for example, water lilies – see Section 3.8.4). Billabongs such as Yellow Water are also of value due to their tourism and recreational significance (section 3.8.1).

Description

Refer Wetland Types O, Tp and Ts in Section 2.4.2.

Patterns in Variability

The spatial arrangement of palustrine wetlands within the landscape emulates some constancy due to geology and topo-climatic patterns, however the distribution and abundance of wetland plant species exhibits substantial natural variation over time (Finlayson 2005). Parameters contributing to the dynamic nature of palustrine wetlands may include rainfall, fire and magpie goose *Anseranas semipalmata* foraging.

While broad-scale mapping of billabongs are available (refer Section 2.4), there are no empirical data describing natural variability of palustrine wetlands over time at a whole-of-site scale. Furthermore, there area no data describing changes in vegetation communities at more localised spatial scales prior to listing.

The only study to date describing temporal changes in vegetation distribution was undertaken on the Magela floodplain (located in Stage II) between 1983 (six years prior to listing) and 2003 (14 years after listing) (Boyden *et al.* 2008). Boyden *et al*. (2008) mapped the relative change in the percentage cover and distribution of eight native vegetation classes in the Magela floodplain (refer Figure 3-4). Most plant classes exhibited little change, except for *Eleocharis* that decreased by 57 percent and *Nelumbo* that decreased by 85 percent. While this study considered changes occurring both before and after site listing, the study provides a basis for demonstrating the nature of temporal variability in these communities.

Empirical data for billabongs are limited to the mapping layer for the catchment of the South Alligator River (refer Section 2.4.2). As such, patterns in natural variability over time can not be quantitatively described. However, it is known that a high degree of variability is exhibited by billabongs in terms of their size and permanency, predominantly due to seasonal and annual variations in climatic parameters (particularly rainfall) (for example, see Finlayson *et al.* 2006).

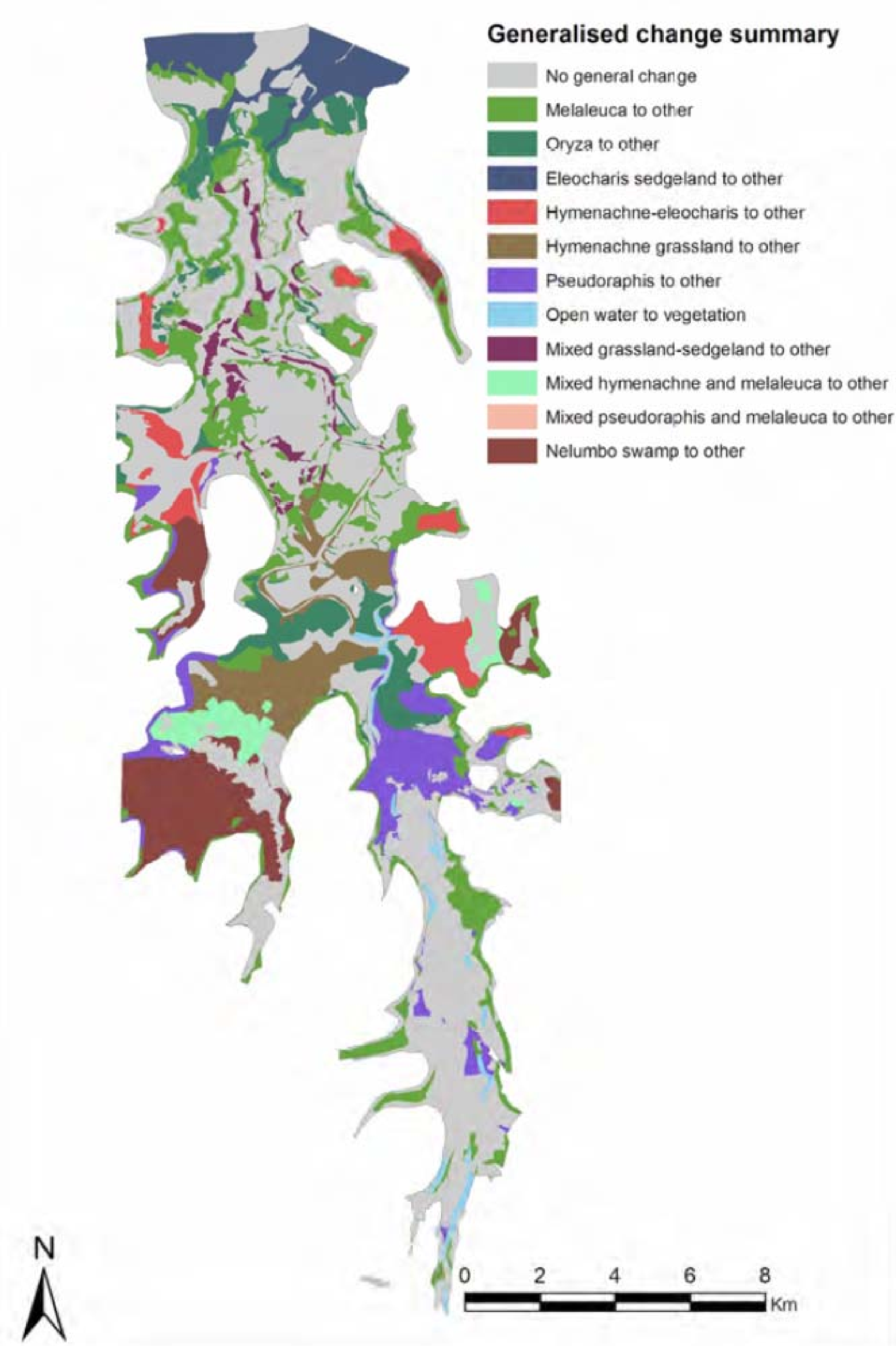


Figure 3-4 Generalised vegetation class changes on the Magela floodplain between 1983 and 2003 (source: Boyden *et al.* 2008)

3.3.4 C4 – Waterfalls, Seeps and Waterholes

Reasons for Selection as 'Critical'

Key features that were identified in proposals for the National Park declaration included the plateau and its gorges and the wilderness values of these areas, as well as the main escarpment, scenic landforms and associate flora and fauna (refer Fox *et al*. 1977). Furthermore, these habitats were selected as a critical component as they support endemic aquatic invertebrates (Criterion 3 and Critical Service 1) and provide opportunities for recreation, tourism and scientific research (for example, Wilson *et al.* 2009).

Description

As briefly mentioned in Section 2.4.2, the sandstone cliffs of the Arnhem Land Escarpment in Kakadu National Park contain a number of waterfalls. Water levels of the creeks forming the waterfalls typically drop very quickly at the end of the wet season, and the waterfalls are either greatly reduced in volume or may totally dry up, leaving a number of deep pools at the base of the escarpment.

The top of the plateau is generally a harsh and dry environment. However, water seeping from rock walls, together with deep alluvial soils, has allowed development of tall monsoon forests within gorges. These habitats are important for fauna refuge during the drier months, and also support a number of threatened flora species[2]. In places the dominant plant species is *Allosyncarpia ternata*, a tree species that is endemic to the Kakadu and Arnhem Land region.

Patterns in Variability

There are no empirical data describing variability over time in extent of permanent waterholes and seeps in the stone country.

3.3.5 C5 - Populations of Migratory and Resident Waterbirds

Reasons for Selection as 'Critical'

Populations of migratory and resident waterbirds are fundamental to determining the site's ecological character, and were noted as a feature of importance with respected to proposals for declaration of the National Park (refer Fox *et al.* 1977). Furthermore, populations of migratory and resident waterbirds were selected as a critical component due to the support for Ramsar Nomination Criteria 4 and 5, the opportunities presented for recreation and tourism, the provisioning of traditional foods (Section 3.8.4) and opportunities presented for scientific research (for example, Traill *et al.* 2010a,b).

[2] Note that these flora species are not wetland-dependent and have therefore not been considered in this ECD in the context of Ramsar Nomination Criterion 2.

Description

The Ramsar site supports significant overall numbers of waterbirds, as well as significant numbers of individual bird species. Specific details have been described for justification of the Ramsar Nomination Criteria in Sections 2.5.7 and 2.5.8 (also see Appendix C for waterbird species list).

Waterbirds feed on aquatic invertebrates, vertebrates such as fish and frogs, and plant material. As such, these populations of migratory and resident waterbirds are important to ecosystem functioning, particularly with respect to wetland nutrient cycling processes. Herbivorous birds (for example, magpie geese *Anseranas semipalmata*, wandering whistling duck *Dendrocygna arcuata*) are most abundant and are supported by the vast expanse of vegetation.

Waterbirds are also important with respect to plant recruitment processes. Specifically, waterbirds may disperse seeds through endozoochory (ingestion of seeds) or epizoochory (for example, transportation of seeds in mud stuck to feet), and intensive turning over of floodplain soils occurs as a result of magpie geese foraging for water chestnut *Eleocharis dulcis* tubers.

Species that are listed under international migratory agreements are listed in Appendix C. Important sites for migratory shorebirds include:

- intertidal feeding habitats of Field Island (roost and intertidal feeding sites); the coast between Finke Bay and East Alligator and between the South Alligator River and Minimini Creek (and nearby open saline wetlands)
- roost sites of Field Island and beaches of West Alligator Head area (especially Middle Beach – an important mainland site)
- inland wetlands associated with all the major rivers, including: Gulungal, Narramoor, Kapalga South, Kapalga Ruins, Fischer's Hole Billabongs; Magela Creek; Mirangie Spring, Obiworbby Spring, Gaden's Spring, Boggy Plain, Causeway Point, Jarrahwingkoombarngy Swamp, and Billyangardee Spring, and
- for individual species – the mouth of East Alligator River (black-tailed godwit *Limosa limosa*); South and East Alligator River wetlands (lesser sand plover *Charadrius mongolus*), and Boggy Plain, Jarrahwingkoombarngy Swamp and Billyangardee Spring (little curlew *Numenius minutus*).

There is a range of biological processes that, together with physical (abiotic) processes described elsewhere, are critical to the maintenance of wetland ecosystem functioning and waterbird values. The availability of food sources will affect the frequency and intensity of use of the site as a feeding habitat by waterbirds, noting that a broad range of feeding techniques are used by the array of waterbirds that use the site. These feeding adaptations range from shorebirds feeding on macroinvertebrates within intertidal habitats to herbivorous waterbirds of the freshwater floodplain wetlands. The following is a summary of some of the key processes which are required to maintain feeding habitat values for waterbirds:

- freshwater flow regimes to support freshwater wetland characteristics and buffers to increasing salinity levels

- primary and secondary productivity of aquatic flora, algae and micro- and macro-invertebrates within shallow wetland habitats
- water quality to a level required to support high primary and secondary productivity, and
- maintenance of natural patterns of tidal inundation. Tidal inundation influences intertidal feeding habitat characteristics, that is, overall extent, productivity and daily availability to shorebirds.

Patterns in Variability

For the majority of waterbird species, birds appear to migrate into the Alligator Rivers Region from shallower floodplains to the west, from sub-tropical areas to the south, from distant locations in southern Australia, and from the northern hemisphere (Morton *et al.* 1993a,b, Bamford 1990, Bayliss and Yeomans 1990, Chatto 2000-2006). For waterbirds (excluding migratory shorebirds), a consistent pattern in changes in waterbird abundance is primarily linked to the seasonality of rainfall and the annual wetting and drying cycle of tropical wetlands (Morton *et al.* 1990a, Bayliss and Yeomans 1990, Chatto 2006). Rainfall is highly seasonal so that wetlands are flooded annually (wet season December to March) and then followed by an extended dry season (April to November). For waterbirds (excluding migratory shorebirds), this pattern of abundance is generally characterised by lower numbers during the wet season (typically dispersed throughout floodplain habitats to nest), then increasing to dramatic peaks in the late dry season and concentrating in higher densities at remnant wetlands as the only remaining sources of permanent freshwater and food (Morton *et al.* 1990a, 1993c). The influx is typically dominated numerically by magpie geese, but all species become more abundant in the dry season (Morton *et al.* 1990a; Bayliss and Yeomans 1990; Chatto 2006). Whilst variations in abundance and distribution between years within the same season have been recorded, the most likely explanation is reflected in annual and local variations in rainfall (Morton *et al.* 1990a).

In regards to the migratory shorebird component of the waterbird assemblage, there is an increase in numbers between July and September (linked to the arrival of birds migrating from northern breeding grounds), then followed by a decline over the wet season as some birds continue migration or move into freshly inundated wetlands, then an exodus of those remaining birds from May to July (Chatto 2006). There is some evidence which indicates that there is variation in the timing of peak abundance of certain species (though not significantly altering the overall pattern of shorebird abundance mentioned above) and this is probably linked to differences in migratory paths used to enter and depart from Australia (Geering *et al*. 2007). Examples include higher abundances coinciding with northern migration (marsh sandpiper *Tringa stagnatilis*, common sandpiper *Actitis hypoleucos*, sharp-tailed sandpiper *Calidris acuminata*) and southern migration (little curlew, oriental pratincole *Glareola maldivarum*) (Chatto 2003b, 2006). Differences in a species' use of site on southward and northward migration elsewhere within the flyway have been widely reported (for example, Minton 2004, Gosbell and Clemens 2006). Interpretation of changes in abundance for migratory species needs to also consider potential external factors (potential variability in breeding success) and in particular, anthropogenic impacts to key stopover sites within other parts of the flyway.

Of the three general functional groupings of migratory shorebirds recorded in Kakadu National Park (species of marine shorelines; species of freshwater shorelines; and species of grasslands), Bamford (1990) noted that most species of freshwater shorelines and grasslands were scarce or absent from early wet season (December) until towards the end of the following dry season (September-

November). Of these, the little curlew provides a dramatic example, where numbers may increase dramatically within a short period (30 000 to 50 000 birds recorded), and then plummet, all within the period September through to October with a large proportion of the population moving to the sub-coastal floodplains some distance to the east and west of the Alligator Rivers Region (Bamford 1990, Morton *et al.* 1991). Those species of marine shorelines, not unexpectedly, do not exhibit the concomitant pattern of change in abundance as their preferred wetland habitat is not affected to the same extent by the seasonal effects of flooding and drying.

3.3.6 C6 – Populations of Freshwater Fish

Reasons for Selection as 'Critical'

Freshwater fish are a key component of aquatic ecosystems throughout the Ramsar site, and were noted as an important biological feature in proposals for National Park declaration (refer Fox et al. 1977). The importance of freshwater fish populations within the site is also reflected through the support of Ramsar Nomination Criterion 7, the presence of endemic species (Service 1) and the fisheries resource values provided by the site (Critical Service 2).

Description

Freshwater fish abundance and diversity in Kakadu National Park are high in an Australian context (Allen et al. 2002). Freshwater fish can be found in all aquatic habitats, including floodplain wetlands, billabongs, creeks, rivers and permanent pools at creek headwaters in the escarpment. Due to differences in habitat characteristics and food resources, the greatest fish diversity is supported by channel, backflow and floodplain billabongs, whilst escarpment habitats and sandy creek beds typically contain the lowest fish diversity (Cowie *et al.* 2000).

Freshwater fish are a key dietary component for the top aquatic predators in the site (for example, crocodiles, fishing eagles) and therefore contribute to controlling ecosystem processes and biological interactions. Barramundi are also opportunistic predators, primarily feeding on aquatic invertebrates and fish. Typically the diet of larger barramundi consists of 60 percent fish and 40 percent crustaceans (predominantly prawns/shrimp), whilst smaller barramundi primarily feed on crustaceans (Allsop *et al.* 2006).

Densities of freshwater fish are highly seasonal and are related to flooding and water depth. Most fish migrate seasonally, moving out of dry season refuges at the start of the wet season to colonise wetted creeks, floodplains and billabongs (Cowie *et al.* 2000). The proliferation of freshwater fish during the wet season and their progressive concentration in shrinking water bodies from mid to late dry season presents ideal feeding conditions for fish-eating birds (Cowie *et al.* 2000). Exclusively fish-eating species include darters *Anhinga novaehollandiae*, little black cormorants *Phalacrocorax sulcirostris*, Australian pelicans *Pelecanus conspicillatus*, ospreys *Pandion haliaetus* and great egrets *Ardea alba*.

Freshwater fish communities in the upper Arnhem Land escarpment are distinctly different to those in the lowland floodplain habitats as a result of a gradient in environmental conditions occurring along the creek systems of the site (Gardner *et al.* 2002). Escarpment communities inhabit aquatic areas with low temperatures, high dissolved oxygen and low turbidity over a rocky substrate. In contrast, habitats in the lower freshwater reaches are typically warmer, with lower dissolved oxygen and soft sediment substrates (Gardner *et al.* 2002).

Most freshwater fish migrate seasonally, moving out of dry season refuges (for example, permanent billabongs) at the beginning of the wet season to colonise floodplains. The main purpose of undertaking these migrations is to benefit from increased food availability during the wet season and to breed (Griffin 1995, Cowie *et al.* 2000). Most of the fish species in Magela Creek, a seasonally flowing tributary of the East Alligator River, show a peak in breeding activity soon after the start of the wet season (Bishop and Forbes 1991).

Approximately 20 percent of species within the Alligator Rivers Region are catadromous, migrating from freshwater areas to breed in marine or estuarine environments (Bayliss *et al.* 1997). The remaining fish species are typically potadromous and do not have an obligate estuarine phase (i.e. primarily migrate from rivers to floodplain areas to use increased habitat and food availability during the wet season). Perhaps the most important catadromous fish species within the site is barramundi *Lates calcarifer* (refer Section 3.7.2). Mature barramundi (and also possibly the Ord River mullet and tarpon) migrate to coastal areas early in the wet season to breed. Barramundi eggs and larvae require saltwater so spawning occurs from September to February in coastal swamps, river mouths and marine embayments (Davis 1985; Allsop *et al.* 2006).

Towards the end of the wet season there is a large migration of adult and juvenile fish upstream from coastal areas to permanent freshwater bodies (Bishop and Forbes 1991). These upstream migrations are thought to be crucial to transferring assimilated aquatic productivity from floodplain areas to the less productive rivers and streams. For example, in Magela Creek, the upstream migration of black-striped rainbowfish *Malanotaenia nigrans* has been estimated to be up to one tonne wet weight per day, which is almost an order of magnitude greater than the downstream migration (Pidgeon and Boyden 1993).

Patterns in Variability

There are few data describing temporal patterns in fish abundance in the periods prior to listing of the Ramsar site. Data on abundance and size distribution of fish species in eight pools within Magela Creek (Stages I and II) during a sampling season in 1981 is presented in Woodland and Ward (1992). Spangled perch *Leiopotherapon unicolour* and bony bream *Nematalosa erebi* were the most dominant species according to biomass, while Magela hardyhead *Craterocephalus marianae* was numerically the most dominant species at the start of the study, prior to suffering high levels of predation by larger fish (Woodland and Ward 1992). Surveys were not systematic so do not constitute a baseline for identifying changes in communities.

As noted, many of the freshwater species within the site are migratory, therefore diversity and abundance of fish assemblages vary greatly at different times of year, even in permanent waterbodies. During major migration times, fish numbers can also vary greatly from day to day (Humphrey *et al.* 2005).

Based on long-term data from Magela Creek, Gardner *et al.* (2002) note a number of patterns in freshwater fish community dynamics as follows:

- Annual variation in community structure showed species richness was highest in the late-dry and early-wet season, and was also greatest in shallow muddy lagoons.
- Muddy channel lagoons (backflow billabongs) had the lowest annual variability.
- Many fish species demonstrated a preference for particular structural habitat features (for example, substrate type) and, to a lesser extent, physicochemical parameters such as water depth.

Long-term fish monitoring studies by the Australian Government Environmental Research Institute of the Supervising Scientist (*eriss*) provide a basis for assessing long-term patterns in fish species richness at Mudginberri Billabong (Magela Creek – Stage II) and Sandy Billabong (Nourlangie Creek – Stage I) (for example, Woodland and Ward 1992, Gardner *et al*. 2002, Humphrey *et al.* 2005). These surveys were undertaken using systematic methods and therefore constitute a reliable baseline (that is standardised fish counts along 50 metre transects). Note that the fundamental processes that control fish communities in these billabongs are not known to have been fundamentally altered since the time of listing, therefore these data are expected to represent a reliable baseline.

Table 3-4 Mean abundance (number fish per 50 metres) of fish species from Mudginberri and Sandy billabongs for the period 1994 to 2005 (source: Humphrey *et al.* 2005)

Scientific Name	Common name	Mudginberri		Sandy	
		Abundance	% total	Abundance	% total
Craterocephalus stercusmuscarum	Fly-specked hardy head	397.2	52.9	356.8	65.4
Melanotaenia splendida inornata	Chequered rainbow fish	255.4	34.0	47.4	8.7
Ambassis spp.	Glassfish (*A. agrammus, A. macleayi)*	49.1	6.5	72.2	13.2
Amniataba percoides	Banded grunter	15.1	2.0	41.6	7.6
Denariusa bandata	Penny fish	12.9	1.7	2.16	0.4
Glossamia aprion	Mouth almighty	8.5	1.1	10.1	1.9
Nematalosa erebi	Bony bream	2.163	0.288	2.323	0.426
Leiopotherapon unicolor	Spangled grunter	2.050	0.273	0.713	0.131
Toxotes chatareus	Archer fish	2.037	0.271	4.927	0.904
Glossogobius spp.	Goby (*G. giurus & G aureus*)	1.470	0.196	1.260	0.231
Strongylura krefftii	Longtom	1.3	0.173	0.407	0.075
Syncomistes butleri	Sharp-nosed grunter	1.02	0.136	2.837	0.520
Lates calcarifer	Barramundi	0.987	0.131	0.283	0.052
Hypseleotris compressa	Carp gudgeon	0.563	0.075	0.0	0.0
Hephaestus fuliginosus	Sooty grunter	0.473	0.063	0.797	0.146
Neosilurus ater	Black catfish	0.337	0.045	0.780	0.143
Oxyeleotris spp.	Sleepy cod (*O. lineolata & O. selheimi*)	0.217	0.029	0.103	0.019
Pingalla midgleyi	Black-anal-fin grunter	0.15	0.020	0.143	0.026
Liza spp.	Mullet spp	0.103	0.014	0.133	0.024
Neosiluris hyrtlii	Hyrtl's catfish	0.097	0.013	0.013	0.002
Scleropages jardini	Saratoga	0.043	0.006	0.090	0.017
Melanotaenia nigrans	Black-striped rainbowfish	0.030	0.004	0.093	0.017
Mogurnda mogurnda	Purple-spotted gudgeon	0.023	0.003	0.003	0.001
Oxyeleotris nullipora	Dwarf gudgeon	0.023	0.003	0.0	0.0
Megalops cyprinoides	Ox-eye herring	0.013	0.002	0.017	0.003
Arius leptaspis	Salmon catfish	0.007	0.001	0.017	0.003
Pseudomugil tenellus	Delicate blue-eye	0.007	0.001	0.0	0.0
Scatophagus argus	Spotted scat	0.003	>0.001	0.0	0.0
Redigobius bikolanus	Speckled goby	0.003	>0.001	0.0	0.0
Craterocephalus marianae	Mariana's hardyhead	0.0	0.0	0.067	0.012
Pseudomugil gertrudae	Spotted blue-eye	0.0	0.0	0.003	0.001
Anodontiglanis dahli	Toothless catfish	0.0	0.0	0.02	0.004
Arius graeffei	Blue catfish	0.0	0.0	0.003	0.001
Total		751.26	100.0	545.277	100.0
Total no. taxa	34	30		29	
Species density (no./50m)		12.9		13.2	

The results of the long-term fish monitoring program undertaken by *eriss* are documented by Humphrey *et al.* (2005). At Mudginberri and Sandy Billabongs, the species with the highest abundances were typically fly-specked hardyhead *Craterocephalus stercusmuscarum*, followed by chequered rainbowfish *Melanotaenia splendida inornata* and banded grunter *Amniataba percoides* (refer Table 3-4, Humphrey *et al*. 2005). At Mudginberri Billabong, a total of 30 species was recorded, with mean species density of 12.9 species per 50 metre transect, and at Sandy Billabong a total of 29 species was recorded and the mean species density was 13.2 species per 50 metre transect (Humphrey *et al*. 2005). The mean species density values recorded by Humphrey *et al.* (2005) were comparable to baseline species richness values recorded by Bishop *et al.* (1990), despite differences in sampling methods and effort.

3.3.7 C7 – Populations of Freshwater and Saltwater Crocodiles

Reasons for Selection as 'Critical'

Saltwater and freshwater crocodiles represent critical components not only in terms of their ecological roles within the site, but also in terms of their iconic and cultural values.

Description

Saltwater Crocodiles

The Australian distribution of saltwater crocodile *Crocodylus porosus* extends across the north from Broome and down the east coast to Gladstone. They inhabit both salt and fresh waters, including tidal rivers, estuaries, nearby freshwater billabongs, lagoons and wetlands. Saltwater crocodiles also bask on riverbanks and sandbars.

Saltwater crocodiles are opportunistic predators with a wide ranging diet, feeding in channel, billabong and floodplain habitats. In Kakadu National Park, the diet of juveniles largely consists of crabs and prawns, as well as fish, amphibians and small reptiles, and larger adults also consume fauna such as birds, kangaroos, wild pigs and sharks (NTG undated). The relatively high number of saltwater crocodiles in Kakadu National Park means that their predatory activities can have a significant effect on the population dynamics of their prey species. For example, in populations of waterbird species that are not typically present in high numbers, their reproductive success and consequent abundances may be controlled in part by saltwater crocodile predation on eggs, chicks and adult birds, particularly during the wet/breeding season.

Compared with other parts of northern Australia, saltwater crocodile densities are greatest in the Northern Territory, with Kakadu National Park containing a significant proportion of the Australian population (S. Ward pers. comm. 2009). Fukuda *et al.* (2007) suggest that a number of environmental influences are linked to the greater abundances in this area, namely:

- the proportion of a catchment area that consists of favourable wetland vegetation types (*Melaleuca*, grass and sedge)
- rainfall seasonality, and
- temperature (mean temperature in the coolest quarter of the year).

Saltwater crocodiles nest over the wet season between October and May, with an increase in temperature triggering reproductive activities (Webb 1991). The extent and timing of nesting is related to rainfall and water levels in the late dry season: years with high rainfall and cool conditions between August and November are associated with high nesting effort, while years with poor rainfall and hot conditions between August and November are associated with low nesting effort (Webb 1991).

Nest mounds are constructed out of live or dead vegetation and mud. These nests are typically located among dense aquatic grasses or on floating mats, close to a permanent water source (billabong margins, riverbanks etc.) (Grigg and Taylor 1980). The nest mounds are approximately 1.8 metres high, and a hole is excavated in the mound into which approximately 50 eggs are laid (Leach *et al.* 2009) and incubated for 75 to 90 days. The mounds serve a number of functions, including insulation of the eggs from temperature extremes, prevention of dehydration, prevention of predation and minimisation of flood damage to the embryos. There is a high mortality of saltwater crocodile eggs, predominantly due to flooding that may kill over half of the eggs laid each year (Webb and Manolis 1989).

Freshwater Crocodiles

Freshwater crocodiles *Crocodylus johnstoni* are endemic to northern Australia, occurring in Western Australia, Northern Territory and Queensland. They inhabit rivers wetlands, billabongs and creeks, remaining in permanent waters during the dry season. Basking also occurs on riverbanks.

Freshwater crocodiles are ambush predators, with fish and crustaceans (for example, crayfish and shrimp) comprising the majority of their diet, although a significant proportion is derived from other fauna such as amphibians, small reptiles, birds and insects (Cogger 2000). Approximately 40 percent of the diet of freshwater crocodiles is of terrestrial origin (for example, birds, reptiles) (Webb *et al.* 1983).

Freshwater crocodiles typically inhabit the floodplains during the wet season, and move to river channels late in the wet season to stay in close proximity to permanent water during the dry season. Female freshwater crocodiles dig holes in sand embankments as nests. Nesting occurs during the dry season, after the water levels fall and riverbanks are exposed. Early wet season flooding can be detrimental to nesting success as embryos will drown if eggs are inundated. The temperature at which eggs are incubated determines the sex-ratio of hatchlings (Whitehead *et al.* 1990).

Pattern in Variability

Saltwater Crocodiles

Since protection in 1971, the Northern Territory population increased from approximately 3000 post-hatchlings (juveniles to adults age classes) to approximately 70 000 – 75 000 by 1994 (NTG undated) and now represents a large proportion of Australia's saltwater crocodile population.

The most recent information on saltwater crocodile trends in the Kakadu National Park Ramsar site is provided by Britton (2009), who analysed population trends in the four major tidal rivers of Kakadu National Park from 1977 to 2007. For the purposes of the present study, the tidal reaches of Wildman, South Alligator and West Alligator Rivers are considered to occur in Stage II (1989 listing) whereas the tidal reaches of East Alligator are considered to occur in Stage I (1980 listing).

Table 3-5 shows saltwater crocodile densities prior to Ramsar site declaration. Since this time, there has been a general increase in saltwater crocodile densities (refer Figure 3-5). However, this trend was not consistent across all four river systems (Figure 3-6). Saltwater crocodile densities (number counted per kilometre) were generally greatest in the Wildman, East and South Alligator Rivers (Figure 3-6). Densities in the West Alligator Rivers were lower than the other rivers, perhaps due to issues with survey effort and other biases (Britton 2009). There is also a trend of increasing numbers of saltwater crocodiles recorded in freshwater areas, possibly in response to increasing population densities in other more optimal habitats.

Table 3-5 Saltwater crocodile densities prior to site listing in 1980 (Stage I) or 1989 (Stage II) (source: Britton 2009)

River/Stage	*n*	No. per km (Min. and Max.)
East Alligator (Stage I)	2	2.3 – 2.8
West Alligator (Stage II)	5	1.4 – 3.8
South Alligator (Stage II)	5	1.1 – 2.7
Wildman (Stage II)	5	2 – 6.2

Another trend noted by Britton (2009) is that the site's saltwater crocodile population appears to be gradually shifting towards a greater proportion of larger crocodiles (greater than 1.8 metres in length), accompanied by a decline or stabilisation in the proportions of smaller size classes. Britton (2009) suggests this is due the increased densities of large crocodiles, which are known to prey on small crocodiles and drive them out of territorial areas.

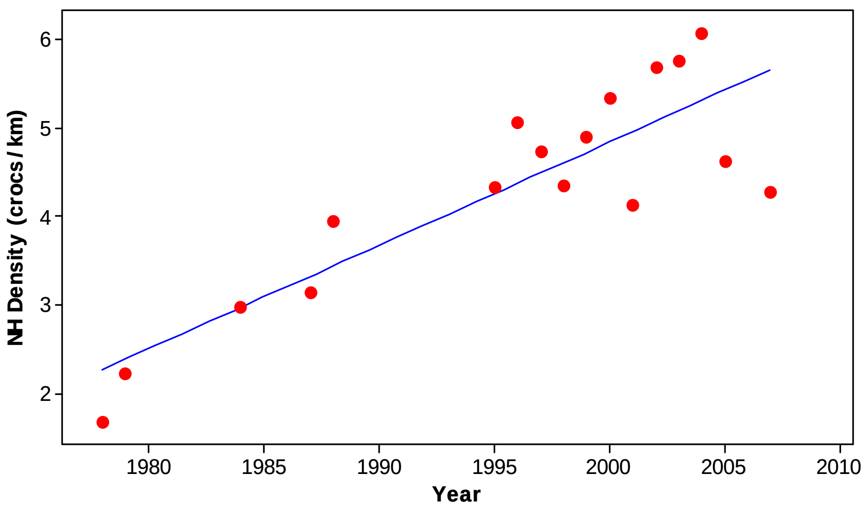


Figure 3-5 Changes in non-hatchling densities of saltwater crocodiles for all four major rivers surveyed in Kakadu National Park – combined data (source: Britton 2009)

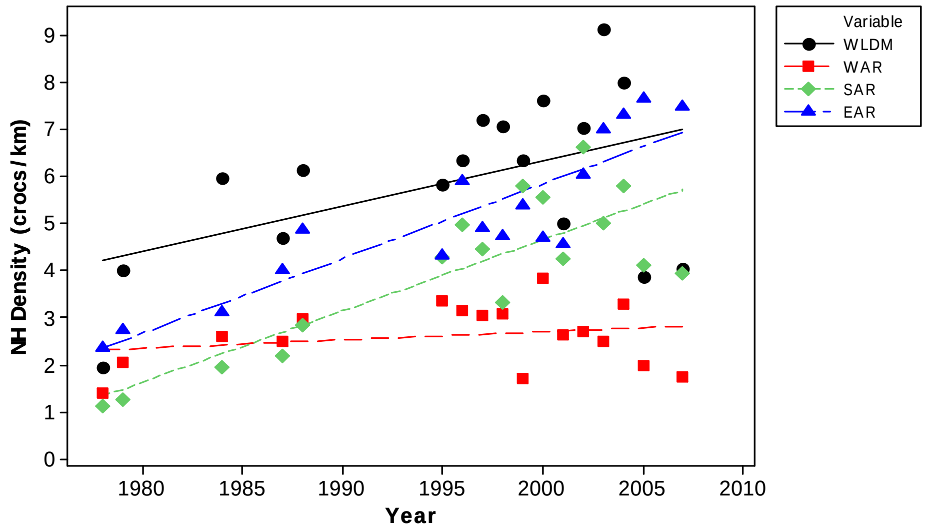


Figure 3-6 Changes in non-hatchling densities of saltwater crocodiles for Wildman River (WLDM), West Alligator River (WAR), South Alligator River (SAR) and East Alligator River (EAR) (source: Britton 2009)

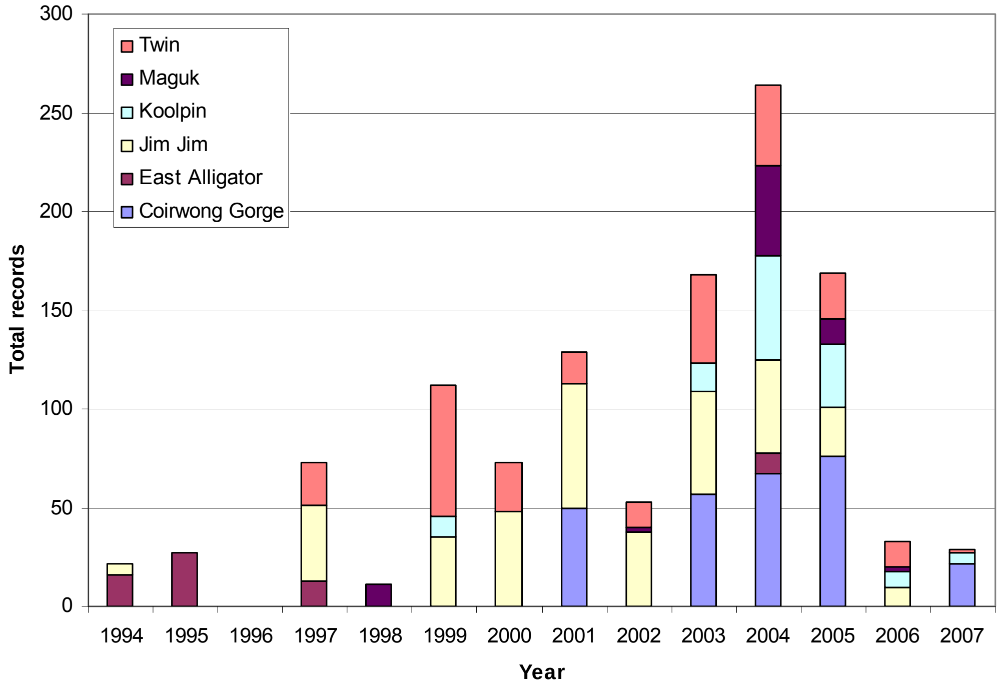
Freshwater Crocodiles

Kakadu National Park has undertaken annual surveys of freshwater crocodiles within the Park since 1994. A summary of the data available from these surveys is presented in Figure 3-7 from 1994 to 2007. The data presented here include data collected from six key freshwater crocodile locations: Twin Falls (Stage I), Maguk (Stage I), Koolpin (Stage I), Jim Jim (Stage I), East Alligator (Stage I and II) and Coirwong Gorge (Stage III). With the exception of Coirwong Gorge which occurs in Stage III (1996), all data were collected following Ramsar site listing.

The greatest numbers of freshwater crocodiles were most consistently recorded at the Jim Jim and Twin Falls areas and Coirwong Gorge. In general, freshwater crocodile sightings during the surveys increased between 1994 and 2007. However, the most recent surveys conducted in 2006 and 2007 show a marked decline in densities, returning to total sighting numbers not recorded since 1998.

In the absence of systematic survey data, it is difficult to assess the likely causal factors for the apparent changes in abundance over time. Given the long life-span and low reproductive success of this species, it is unlikely that the dramatic changes in numbers from one year to the next represent actual changes in population densities. It is far more likely that such dramatic inter-annual changes reflect survey error due to inconsistent levels of sampling effort. For example, the available data suggest that not all locations were surveyed in every year, with some years containing data for only one or two locations (Figure 3-7).

However, it is notable however that the observed decline in sightings is coincident with the timing of cane toads arriving at the site. Letnic *et al.* (2008) recorded mass mortality of freshwater crocodiles in the Victoria River (Northern Territory), with population densities of crocodiles plummeting by as much as 77 percent following arrival of cane toads. The lack of information on the population status of freshwater crocodiles in the Park and the impacts of cane toads on local populations represent key information gaps.



Note: available data does not cover all locations for every year

Figure 3-7 Total freshwater crocodile sightings over time at each location (source: Kakadu National Park, unpublished data)

3.3.8 C8 – Populations of Threatened Sharks

Reasons for Selection as 'Critical'

Kakadu National Park supports two threatened shark species: speartooth shark *Glyphis glyphis* (formerly *Glyphis* sp. A) and northern river shark *Glyphis garricki* sp. nov. Maintenance of populations of threatened species is an important factor contributing to the maintenance of global biodiversity values (see Critical Service 1).

Description

Speartooth shark

Speartooth shark *Glyphis glyphis* (formerly *Glyphis* sp. A) is listed as critically endangered under the EPBC Act and endangered under the IUCN Red List. This species has a restricted and highly fragmented population (refer Section 2.5.11). It has only been captured in tidal rivers and estuaries indicating that large tropical river systems appear to be the primary habitat for this shark, although it has been suggested that this species may move offshore to feed (Stevens *et al.* 2005).

Speartooth sharks hunt close to and among the soft substrate, and feed on fish and large crustaceans. The large number of sensory ampullae and the small eye of the speartooth shark indicate that it may have adapted to feeding on benthic and demersal species in turbid waters (Peverell *et al.* 2006).

There are no data describing natural variability in abundance of this species. In the context of this service, it would appear that the most notable life-history function provided by the site is a feeding area for neonate, juvenile and adult sharks. Note that this species has not been captured outside rivers and estuaries which may suggest that it complete its life-cycle in rivers. Based on tracking studies in the Wenlock River, neonates and juveniles of this species are thought to have highly restricted home ranges that are confined to the upper Wenlock estuary (less than 10 square kilometres stream reach), whereas adults may have wider home ranges (Pillans *et al*. 2008).

Due to the lack of data on specific habitat requirements of this species, it is not possible at this stage to determine critical components and processes supporting this species. It is likely however that the following are important to maintenance of this species (and the northern river shark) within the site:

- presence of suitable prey, including fish and large demersal invertebrates (crabs, prawns etc.) (Critical Component 6)
- physical (tides, fluvial) processes controlling stream morphology and habitat suitability, as well as movement patterns of sharks (Pillans *et al.* 2005; 2008) (Critical Process 1), and
- tidal and fluvial processes controlling important water quality variables (salinity and turbidity) that are thought to determine habitat suitability (see Pillans *et al.* 2008).

Northern river shark

Northern river shark *Glyphis garricki* (formerly *Glyphis* sp. C) is listed as endangered under the EPBC Act and IUCN Red List. This species has a restricted and highly fragmented population (refer 2.5.11), and is thought to be restricted to the relatively shallow, upper freshwater to brackish (0-26 ppt) reaches of the Fitzroy, Adelaide, Mary and Alligator (East, West, South) River systems (TSSC 2001a; Morgan *et al.* 2004; Field *et al.* 2008). Despite considerable fishing and collecting activity in the Northern Territory, no specimens have ever been found in coastal marine habitats (Thorburn *et al.* 2003, Larson *et al*. 2004).

Very little is known of its life-history or ecology. It is likely that the key service offered by the site for this species is a feeding area for juveniles and adults. It is unknown whether the site supports mating or breeding habitat for this species. Refer to speartooth shark for possible controls on abundance.

Patterns in Variability

Insufficient data to assess pre-listing or present day distribution and abundance patterns of either species.

3.3.9 C9 - Yellow Chat Populations

Reasons for Selection as 'Critical'

The site supports one wetland-dependent threatened bird species: yellow chat (Alligator Rivers) *Epthianura crocea tunneyi*. Maintenance of populations of threatened species is an important factor contributing to the maintenance of global biodiversity values (see Critical Service 1).

Description

Yellow chat (Alligator Rivers) is listed as endangered under both the EPBC Act and *Territory Parks and Wildlife Act 2000*. Yellow chat (Alligator Rivers) is endemic to the Northern Territory and is restricted to a small geographic area encompassing the floodplains from the Adelaide River to the East Alligator River, between Oenpelli and Darwin (Armstrong 2004, Woinarski and Armstrong 2006, TSSC 2006).

Yellow chat is typically associated with low vegetation (for example, saltmarsh, samphire, chenopod shrublands or grasslands) bordering wetlands (especially ephemeral wetlands on floodplains) (Higgins *et al.* 2001). Within the Northern Territory, the Alligator Rivers subspecies is only known from a small number of sites. It is mainly found on seasonally-inundated alluvial floodplains where low lying areas support cover of grasses, herbs and sedges, but is also known from vegetated margins of channels, including mangrove stands (Keast 1958; Armstrong 2004). Within the Ramsar site, the majority of recorded sightings are derived from floodplain wetlands associated with the South Alligator River (and north of the Arnhem Highway) (see Figure 3-8).

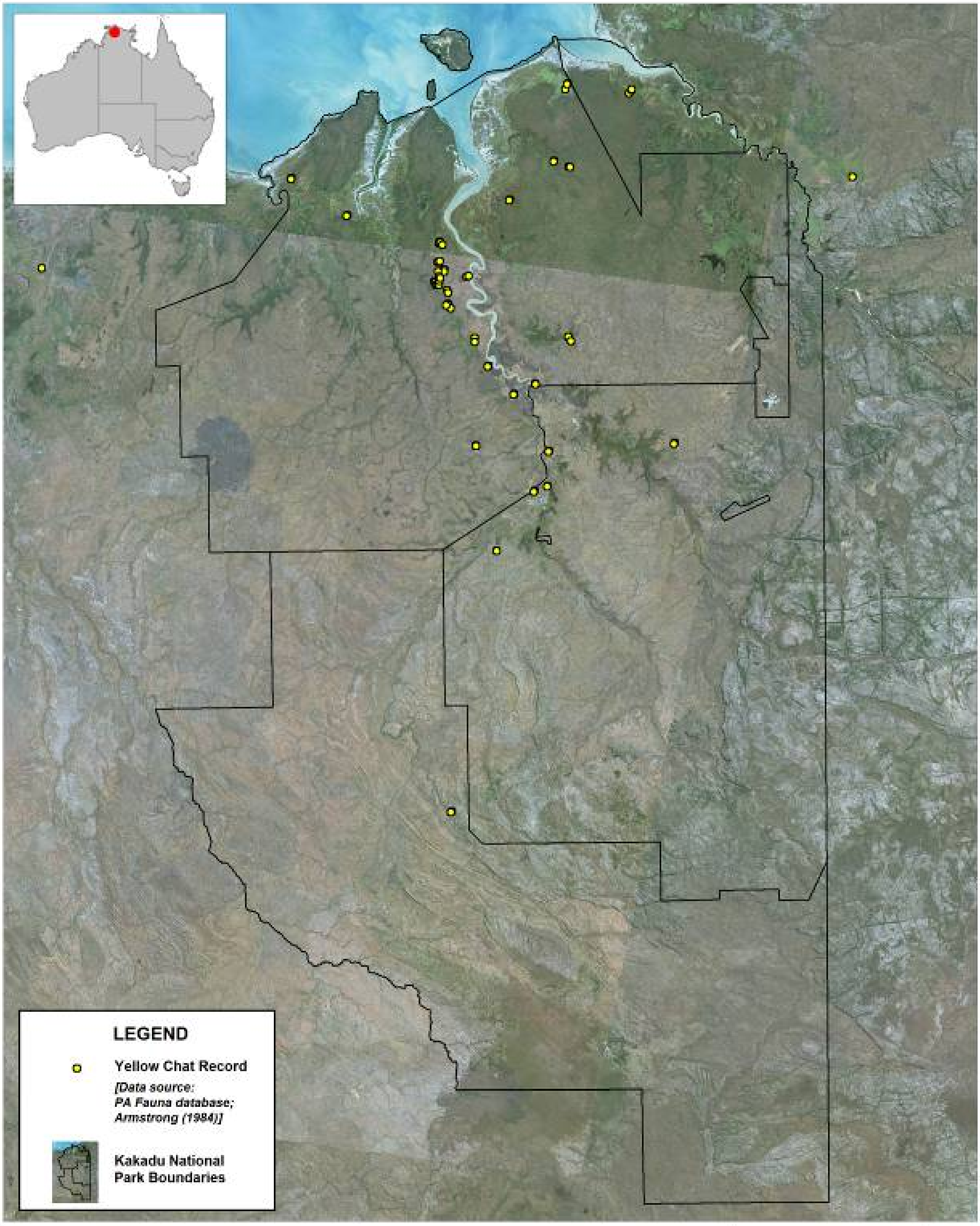
The subspecies is thought to be relatively sedentary (Keast 1958), though known to undertake local movements where they concentrate around wetter areas of floodplain habitat at the end of the dry season (Armstrong 2004). Yellow chat (Alligator Rivers) is mainly insectivorous and typically forages on the ground in dense grass or in low shrubs (TSSC 2006, Woinarski *et al.* 2007).

The subspecies has been suspected to occur in a single contiguous population (Garnett and Crowley 2000) though may actually comprise multiple subpopulations (Woinarski and Armstrong 2006). The extent of occupancy is estimated to be less than 500 square kilometres, based on the extent of the floodplain habitats that yellow chat (Alligator Rivers) has been recorded (Armstrong 2004, TSSC 2006).

There is no accurate information on the total population size for this species, though Garnett and Crowley (2000) conditionally estimated that the number of breeding birds was approximately 500 individuals. The most recent targeted survey undertaken in Kakadu National Park in 2004, estimated that the Kakadu National Park population is probably fewer than 300 individuals (Armstrong 2004). Results from the 2004 survey were regarded as largely comparable to earlier survey records within Kakadu National Park, and providing no evidence of recent decline in numbers within the site (TSSC 2006).

Patterns in Variability

There are no data describing patterns in variability of this species.



Title:
Yellow Chat Records within the Ramsar Sites

Figure: 3-7

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

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3.3.10 C10 - Pig-nosed Turtle Populations

Reasons for Selection as 'Critical'

The site supports the threatened (IUCN-Vulnerable) pig-nosed turtle *Carettochelys insculpta.* Maintenance of populations of threatened species is an important factor contributing to the maintenance of global biodiversity values (see Critical Service 1).

Description

Pig-nosed turtle *Carettochelys insculpta* is listed under as vulnerable under the IUCN Red List, and as a near threatened species under the *Territory Parks and Wildlife Conservation Act 2000*. Pig-nosed turtles have been recorded in South Alligator River (Schodde *et al.* 1972, Legler, 1980, 1982, Press 1986) and East Alligator River (Georges *et al.* 1989).

Pig-nosed turtles are a freshwater species, favouring still waters with an approximate depth of two metres (Legler 1980, 1982, Georges and Kennett 1989). Billabongs along the Alligator River systems are known to represent a significant refuge for this species (Press *et al.* 1995a). Cover for pig-nosed turtles within billabongs is provided by characteristics such as fallen branches, exposed roots and undercut banks.

Pig-nosed turtles are omnivorous, with a diet including leaves, flowers, fruit, invertebrates and fish (Schodde *et al.* 1972). This diversity of food sources enables opportunism, allowing varying exploitation of resources dependent on availability. While males are almost entirely aquatic, females leave the water to nest on sandy banks and lay eggs during the dry season.

The following are important to maintenance of these species within the site:

- presence of suitable habitat in terms of vegetation communities (Components 3 and 4), fluvial hydrology (Process 1) and water quality,
- presence of food resources (Component 6), and
- biological processes including breeding and migration.

Patterns in Variability

Georges and Kennett (1989) found pig-nosed turtles to be widespread between the tidal reaches and the head-waters of the South Alligator River, and that high densities were present in the upper reaches during the dry season (33.8 ± 11.3 turtles per hectare, or 67 turtles per kilometre of channel, in small discrete ponds on the main channel).

There are few quantitative data describing temporal trends in the number of pig-nosed turtles within the site. It is believed that feral animals and other stock caused a decline in the South Alligator River pig-nosed turtle population prior to the declaration of Stage III of Kakadu National Park (1987-1991) (A. Carr pers. comm. in Pritchard 1979), but this decline was not quantified, and it is not clear whether the population has subsequently recovered (TSSC 2005). However, it is known that declines in yellow-spotted monitor lizard *Varanus panoptes* population numbers associated with the arrival of toxic cane toads *Rhinella marina* have reduced predation on pig-nosed turtle eggs by monitor lizards (Doody *et al.* 2006).

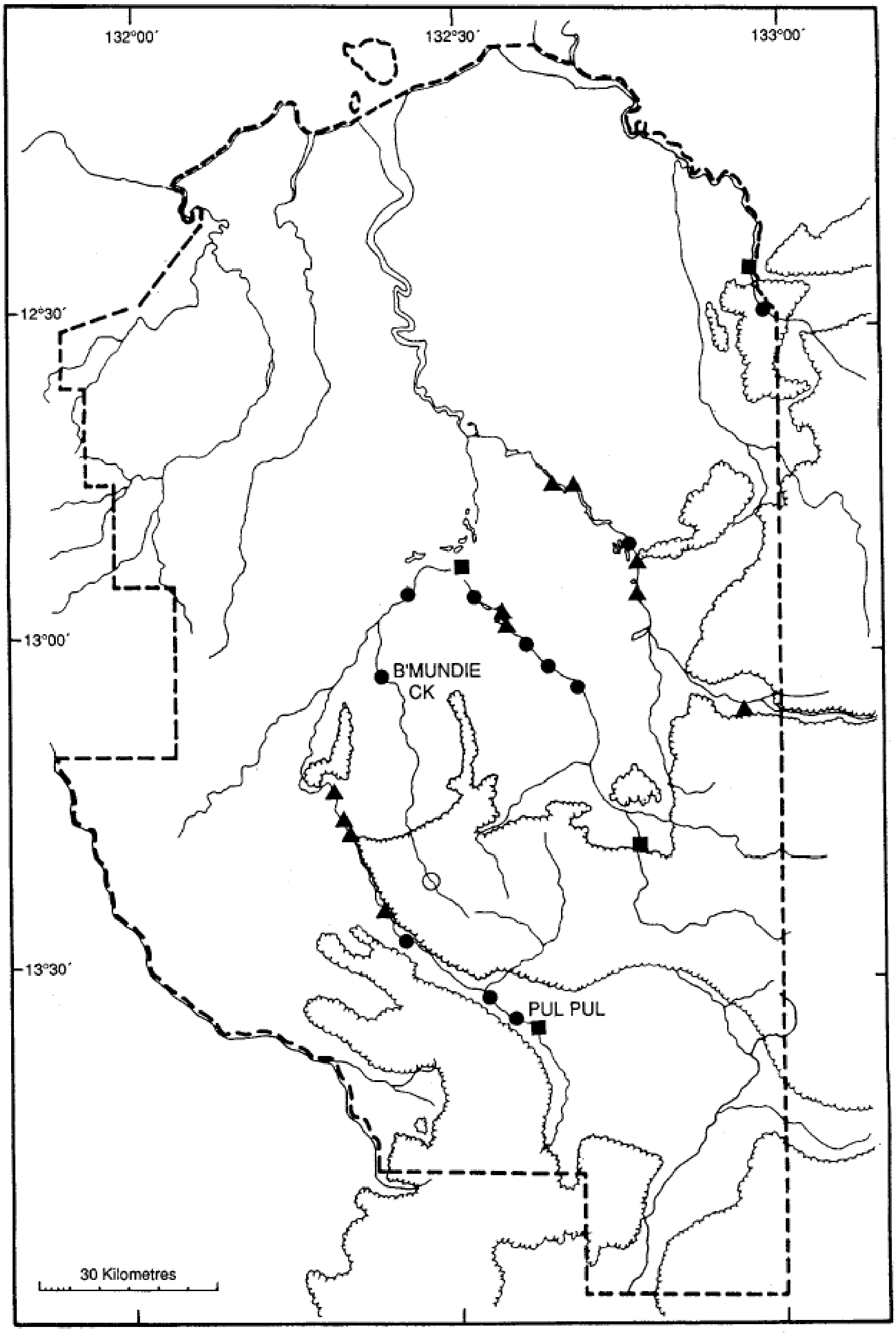


Figure 3-9 Map of know dry season distribution of pig-nosed turtle in the Ramsar site (source: Georges and Kennett 1989)

3.3.11 C11 – Locally Endemic Invertebrate Species

Reasons for Selection as 'Critical'

Support of locally endemic fauna species was selected as a critical component on the basis of support for Ramsar Nomination Criterion 3, as well as the importance of endemic species in terms of justification for National Park nomination (refer Fox *et al*. 1977) and the fundamental importance of threatened species to determining the site's ecological character.

Description

The following aquatic invertebrate taxa are considered to be locally endemic species (occur exclusively within the catchments of the Ramsar site and the Arnhem Plateau – see Appendix D):

- An endemic family of shrimps (Kakaducarididae), which contains two mono-specific genera, namely *Leptopalaemon gagadjui* and *Kakaducaris glabra*. *Leptopalaemon gagadjui* typically occurs in upland permanent streams in the north-western area of the Arnhem Land plateau and is widely distributed (South Alligator River, Nourlangie and Magela Creeks, Namarrgon Gorge), while *K. glabra* is restricted to a single location (the type location in Lightning Dreaming Creek, Namarrgon Gorge) (Bruce 1993, Page *et al.* 2008, refer Appendix D).
- A genus of isopod (*Eophreatoicus;* Family Phreatoicidea) that reportedly has exceptional species-level diversity (approximately 30 species lineages, Wilson *et al*. 2009). Specimens have been collected from the King River region of western Arnhem Land, and various aquatic habitats associated with the west Arnhem Land plateau and escarpments, including sites in the East Alligator (for example, Magela, Ngarradji and Catfish Creeks), South Alligator, Katherine and Liverpool River catchments (Wilson *et al.* 2009, refer Appendix D). The species within this genus are extremely narrow range endemics, with juveniles migrating very small distances downstream (approximately two to six kilometres) from their headwater refuges (Wilson *et al.* 2009).
- At least one species of mayfly from the family Leptophlebiidae (see section 2.5.3).

These species occur exclusively in upland areas, specifically the ancient stone country. Humphrey (1999) identified two key controls on endemism in the stone country:

- the antiquity and persistence of the escarpment and associated perennial streams, springs and seeps, and
- isolating mechanisms, including processes leading to fragmentation of habitat operating over geological time-scales (climate change, erosion etc.), and the generally poor dispersal characteristics of the crustaceans.

Note that regional endemic species (including fish, aquatic plants and invertebrates) are considered as supporting components in section 3.4.6.

Patterns in Variability

There are few data describing patterns in variability of these endemic aquatic invertebrate species. This is because it is only relatively recently that many of the endemic invertebrates have been observed, with most remaining undescribed (for example, *Eophreatoicus*; Wilson *et al.* 2009).

3.4 Supporting Components

The supporting components outlined below are considered to be important or noteworthy in the context of maintaining the character of the site, but are not considered to represent critical components in the context of the considerations outlined in section 3.1.1 of this report. In this context:

- The supporting components are not, in isolation, thought to fundamentally underpin the identified critical services/benefits. However, supporting components may, in combination with other critical and supporting components, underpin critical services/benefits.
- Some supporting components are already partially covered by other critical components, processes or services/benefits.
- The supporting components, while not critical, are important to wetland functioning and are noteworthy in this regard.

3.4.1 Seagrass

There are no empirical data describing variability in seagrass-meadows cover over time, nor are their data describing seagrass extent prior to the Ramsar site declarations.

As discussed in section 2.4.1, a one-off snap-shot of seagrass coverage of the site (and surrounding areas) was undertaken by Roelofs *et al.* (2005). This survey was undertaken post-Ramsar declaration. It is unknown whether the seagrass extent mapped by Roelofs *et al.* (2005) was representative of conditions the time of listing (that is, Stage II 1989). However, in qualitative terms it is known that tropical seagrasses can show great changes over time in response to disturbance by waves and flooding (for example, Preen *et al.* 1995, Kendrick *et al.* 1999, Campbell and McKenzie 2004). The dominant seagrass species within the site are pioneer species that can rapidly recolonise following disturbance (Bridges *et al.* 1981; Birch and Birch 1984). Consequently, when considering natural variability in seagrass extent over time, episodic changes must be taken into account.

3.4.2 Monsoon Rainforests and Riparian Vegetation

Some but not all monsoon rainforests patches can be associated with seeps, which constitute a type of wetland. Riparian vegetation has been included in this component due to the overlaps in spatial distribution and species composition between these two habitat types. However, it is to be noted that certain riparian communities would also be classified as Component 4 (*Melaleuca* forests). Monsoon rainforests and/or riparian vegetation communities are associated with Wetland Types M, N and Y (refer Section 2.4.2).

There are no broad-scale empirical data describing variability over time in extent of riparian and/or monsoon rainforest supported by springs within the Ramsar site (refer section 2.4.2). Banfai and Bowman (2006) examined aerial photography to document changes at 50 rainforest patches over time, which incorporated both riparian vegetation as well as 'non-wetland-dependent' vegetation patches. Four time periods were selected: 1964 (pre-listing), 1984, 1994 and 2004.

Banfai and Bowman (2006) found that rainforest boundaries were highly dynamic at the decadal scale, with a landscape-wide expansion of rainforest boundaries exhibited between 1964 and 2004

(Figure 3-10). Rainforest patch size increased by an average of 15 percent between 1964 and 1984, around seven percent between 1984 and 1994 and about six percent between 1994 and 2004. This suggests a relatively constant average rate of increase over decadal scales, both before and after site listing. This expansion was attributed to global environmental change phenomena such as increases in rainfall and atmospheric carbon dioxide (Banfai and Bowman 2007). It is to be noted that it is unknown whether, or what proportion of, the particular patches of rainforest that were investigated as part of the study were supported by springs (that is, wetland type Y) or were riparian vegetation (that is, wetland types M and N).

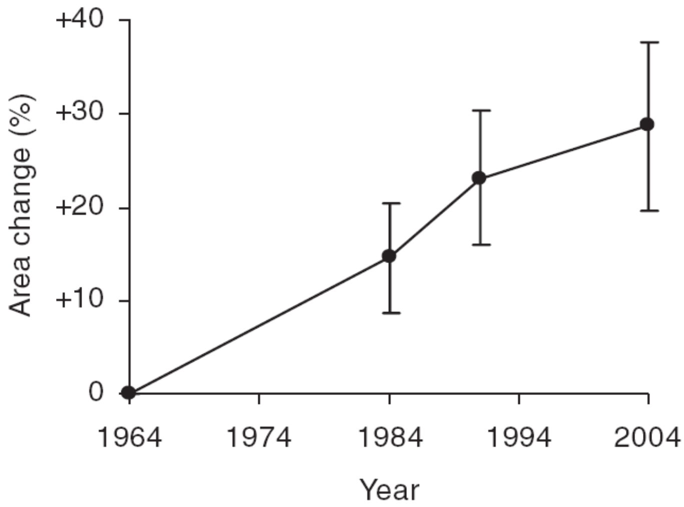


Figure 3-10 Changes in area of monsoon rainforest within Kakadu National Park (source: Banfai and Bowman 2006)

3.4.3 Other Wetland Habitats

As outlined throughout this document, wetland habitats are an exceptionally important feature of the Ramsar site that supports a variety of natural and cultural values. All wetland types present within the site have been described in Section 2.4 (with further details provided in Section 3.3 for wetland types that are seen as 'critical' in the context of this ECD).

3.4.4 Terrestrial Habitats

As previously mentioned, terrestrial habitats comprise large expanses of the Ramsar site. Specifically, the greater part of Kakadu National Park is savannah of Eucalypt-dominated open forest and woodland formations, typically with tall grassy understoreys (Russell-Smith 1995). Additionally, areas of heath are present and the plateau features scattered hardy shrubs and spinifex grasses (Russell-Smith 1995). The terrestrial habitats support a variety of fauna species, many of which use resources from a combination of terrestrial and wetland habitats (refer Section 2.5.5). Terrestrial flora and fauna species are an integral part of the wetland ecosystems, contributing significantly to wetland functions and processes such as energy and nutrient cycles (Finlayson *et al.* 2006).

3.4.5 Aquatic Invertebrates

Kakadu National Park supports highly diverse and abundant aquatic invertebrate populations (Outridge 1987; Finlayson *et al.* 1990). Aquatic invertebrates are consumers that have a vital role in the decomposition and uptake of nutrients in aquatic ecosystems, such that nutrients are processed and available for higher consumers (that is species that prey on aquatic invertebrates). As discussed in Section 3.5.5, some aquatic invertebrate species such as shrimp can have a particularly strong influence on benthic foodwebs by influencing/processing benthic sediments, detritus and algal communities.

In terms of aquatic invertebrates providing a valuable prey resource, almost half of the wetland bird species eat swimming or bottom-dwelling aquatic invertebrates (Cowie *et al.* 2000). These food resources are shared between species on the basis of foraging zones, foraging techniques and prey size. A significant feature of the freshwater fish communities is that they typically lack specialist herbivorous species and most fish species are largely carnivorous (Section 3.2.6) on aquatic invertebrates as a significant feature of the freshwater fish communities is that they typically lack specialist herbivorous species (Cowie *et al.* 2000). MacFarlane (1996) analysed community-based data and found that predation by fish is non-selective of macroinvertebrate taxa. Invertebrates also provide food for aquatic reptiles, with crustaceans in particular comprising a significant proportion of the diets of freshwater and saltwater crocodiles (Section 3.3.7) and pig-nosed turtle (Section 3.2.10).

Aquatic invertebrate fauna can display vast seasonal differences, with species diversity and distribution typically greatest during the wet season (Finlayson *et al.* 1990). Finlayson *et al.* (2006) state that the major aquatic invertebrate families of Kakadu National Park have a high year-to-year constancy compared with other regions of Australia, which is most likely related to the relatively low degree of inter-annual variability in stream flow. Note that endemic aquatic invertebrates are discussed in Critical Component 11 (refer Section 3.2.11).

3.4.6 Regionally Endemic Species

In addition to the local endemic invertebrate species, which represent critical components (see Section 3.2.11), the site contains several regionally endemic species (see also Section 2.5.5). The following aquatic species are considered regionally endemic, meaning they occur exclusively within the Timor Sea Drainage Division):

- Endemic species of Leptophlebiidae mayfly *Tillyardophlebia dostinei*, which has been recorded from a single freshwater stream within the site (Rockhole Mine Creek, Dean and Suter 2004). Dean and Suter (2004) suggest that this species is likely to be more widely distributed, with a possible conspecific recorded at Manning Gorge in north Western Australia (Timor Sea Drainage Division).
- Seven of the nine species of the mayfly family Leptophlebiidae recorded in the Ramsar site are thought to be restricted to the Timor Sea Drainage Division (Finlayson *et al.* 2006).
- Magela hardyhead *Craterocephalus marianae* – This species has a highly restricted geographic range, occurring within the South Alligator River and East Alligator River within the Ramsar site, as well as the Mann River in nearby Arnhem Land (Allen *et al*. 2003). Allen *et al*. (2003) indicates

that this species is abundant within its limited range, forming large schools in fast flowing, shallow creeks with sand or gravel beds.

- Midgley's grunter *Pingalla midgleyi* – This species has a restricted distribution that incorporates the East Alligator River and South Alligator River within the Ramsar site, as well as the upper reaches of the Katherine River (Allen *et al.* 2003). It occurs in well shaded rocky pools in clear, flowing creeks with a sandy bed. It is thought to be common where it occurs (Allen *et al.* 2003).
- Exquisite rainbowfish *Melanotaenia exquisita* – This species has a disjunct distribution, and is thought to be restricted to the South Alligator and Katherine Rivers within the Ramsar site, and upland tributaries of the Edith River (Northern Territory) and the King George River (Western Australia). This species typically inhabits small, clear, swift-flowing streams, often congregating in rock pools at the base of small waterfalls such as Jim Jim Falls in the South Alligator system, Seventeen Mile Falls in the Katherine system (located outside Kakadu National Park), and King George Falls in Western Australia.
- Sharp-nose grunter *Syncomistes butleri* – This species is restricted to the Timor Sea Drainage Division between the Drysdale River (Western Australia) and the Liverpool River (Northern Territory) (Allen *et al.* 2003). It is described as reasonably common in the upper reaches of the large river systems in which it occurs, and is found in slow or fast moving water of lagoons and streams, typically in deeper waters (Allen *et al.* 2003).
- *Bambusa arnhemica* (Poaceae) – A bamboo species that is endemic to the high-rainfall north-western areas of the Northern territory. The species is locally abundant in riparian vegetation, but has a patchy distribution that includes the South Alligator River in Kakadu National Park, and other major watercourses such as the Adelaide, Mary, Finniss and lower Daly Rivers (Franklin and Bowman 2004).
- *Hygrochloa aquatica* (Poaceae) – An aquatic grass species that floats from emerged tufts. This species is endemic to the Top End, occurring from the Daly River to the East Alligator River, and grows on the shallow margins of permanent and seasonal swamps, billabongs and floodplains (Cowie *et al.* 2000).
- *Nymphoides spongiosa* (Menyanthaceae) – An aquatic herb with floating leaves. The species grows in still shallow, freshwater swamps, floodplains and lagoons in Kakadu National Park and neighbouring regions (for example, Mary River, Howard River).
- *Nymphoides subacuta* (Menyanthaceae) – An aquatic herb with floating leaves. The species grows in shallow freshwater swamps and lagoons in Kakadu National Park and the Darwin region.

3.5 Critical Processes

3.5.1 P1 – Fluvial Hydrology

Reason for Selection as 'Critical'

Fluvial hydrology is one of the key drivers of ecosystems and species within the Ramsar site, and is therefore fundamental to determining the site's ecological character.

Description and Patterns in Variability

It is not meaningful to discuss patterns in variability of fluid hydrology pre and post Ramsar listing for several key reasons. Firstly, any one stream can intersect up to three of the Ramsar site Stages, so different pre-listing dates (and baselines) could apply to a single stream. Secondly, patterns in rainfall and hydrology vary greatly over a wide range of temporal scales, including decadal scale variations (see Section 3.5.1). Given the limited amount of long-term data and taking into account these complex longer term cycles, and that processes operating are greater than regional scales will ultimately control hydrology (that is, weather conditions), descriptions of these patterns before and after a time of listing is not meaningful. Patterns in hydrology for the overall data record are therefore briefly described.

The main drainage systems of the Kakadu National Park region begin with run-off from the plateau or start as springs at the foot of the Arnhem Land escarpment (Press *et al.* 1995b). Almost the entire region is drained into Van Diemen Gulf by four main rivers including the East Alligator, South Alligator, West Alligator and Wildman Rivers. The combined catchment area of the four major rivers is about 28 000 square kilometres (Cobb *et al.* 2007).

The four rivers consist of distinctly different stages along their passage to the sea (Press *et al.* 1995b). The first stage consists of the rivers' upper reaches, which typically follow arrow and deep clefts in the sandstone. In the second river stage, the rivers broaden out into braided alluvial channels in the low sandy plains after leaving the plateau country and adjacent hills. This region covers most of Kakadu National Park. Four or more channels are typically separated by banks of loose sands and reformed in times of high flood. These channels divide and distribute their water widely over the third river stage, the expansive floodplains. The floodplains function as a large retarding basin, storing the water up over the wet season and gradually releasing it. The final stage of the rivers is the estuary, which is typically a relatively narrow tidal channel cutting through the floodplains. The South Alligator River has the longest estuarine section, extending approximately 50 kilometres from the sea. The estuarine channel banks are formed by silty levee banks often with a narrow ribbon of mangroves and monsoon rainforest trees in the otherwise mostly treeless floodplains.

Due to the strong seasonality in rainfall in the region, catchment runoff also follows a pronounced seasonal pattern with distinctive wetting up of the catchment in the early wet season followed by large flood flows between January and March (refer Figure 3-11). Stream flows can vary to a large extent due to the wet season rainfall patterns. Typically, wet season stream flows comprise a series of peak flows superimposed on a base flow beginning about mid-December and ceasing about end of June (Press *et al.* 1995b). At the mouths of the two largest rivers, the South and East Alligator Rivers, the estimated annual flows are 2730 and 2560 million cubic metres, respectively. Estimated annual flows for Magela and Nourlangie Creek are 245 and 680 million cubic metres, respectively. However, these estimates may considerably underestimate potential discharges during extreme events (Cobb *et al.* 2007). Petty *et al.* (2008) reported that within the South Alligator River system, wet season flows vary from being contained within steep banks approximately twenty metres across within the South Alligator Valley near Gimbat, to a broad 'sheet' of water kilometres across flowing across the floodplains north of Yellow Water.

By the end of the dry season perennial creeks still flow albeit at a much reduced level, whilst annual creeks are generally dry but may still contain patches of stagnant water as well as billabongs within the creek bed (Petty *et al.* 2008). Major streams in the catchment cease to flow for several months of the year at the end of the dry season (refer Figure 3-11; Table 3-6). High evaporation during the dry season quickly reduces the water levels in pond waterbodies.

Table 3-6 Flow statistics for three representative gauging stations in KNP (source: Australian Natural Resources Atlas website, data from 1958 to 1999)

Location	East Alligator	South Alligator	Wildman
Gauging Station	821019	820112	819001
Time series	1974 to 1999	1960 to 1999	1976 to 1999
Catchment area of station (km^2)	1435	2220	316
Mean annual flow (ML/yr)	1 499 379	1 013 968	99 245
Mean annual flow (mm)	1045	457	314
Mean monthly flow (ML)	116 191	109 801	8018
Mean monthly flow (mm)	81	49	25
Standard deviation (ML)	212 676	193 446	19 734
Minimum monthly flow (ML)	0	0	0
Maximum monthly flow (ML)	1 271 341	1 160 421	135 488
Coefficient of variation	2	2	2

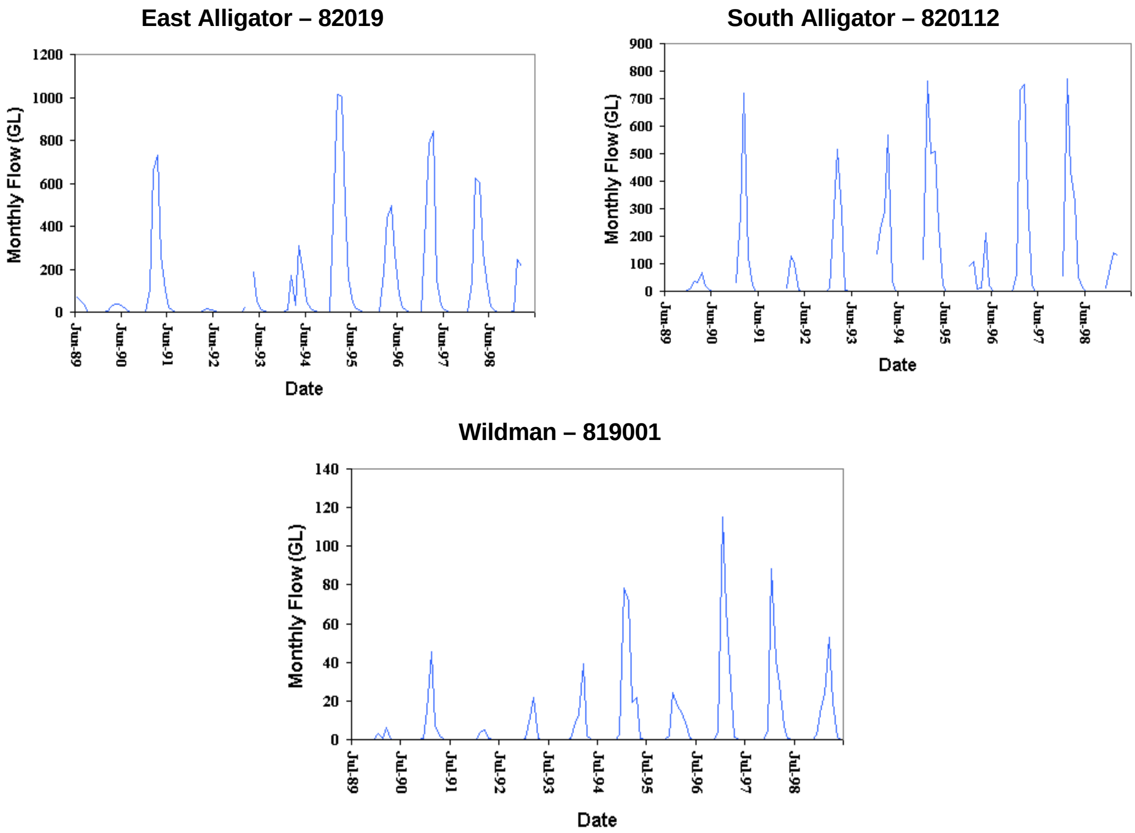


Figure 3-11 Monthly flow at three representative gauging stations in KNP (source: Australian Natural Resources Atlas website, data from 1958 to 1999)

3.5.2 P2 - Fire Regimes

Reasons for Selection as 'Critical'

Fire is one of the major forces that influences dynamics of the landscape, particularly with regard to regeneration processes of vegetation. As such, fire can have significant impacts on the landscape and is important for maintaining species and habitat diversity (Russell-Smith 1995).

Description and Patterns in Variability

The traditional fire regime practised by Bininj created a mosaic of unburnt, early and late burnt patches (Russell-Smith 1995). Fire regimes have been modified since the arrival of Europeans, and occurrences of intense late dry season fires are thought to have increased (Andersen *et al.* 1998, Vigilante and Bowman 2004). Fires experienced at inappropriate (too high or too low) frequencies, intensities or seasonality may lead to substantial changes in vegetation community composition and/or structure.

However, conservation managers now aim to mimic traditional patch burning to encourage optimum biodiversity (Director of National Parks 2007). The approach reduces the amount of grass fuel early in the dry season to assist with preventing late dry season fires covering large areas, thereby ensuring that communities and assets vulnerable to fire are protected (for example, intense late dry season fires result in death of *Melaleuca*).

Fire histories for the region are an important resource for park managers in determining the success of prescribed burning practises. As such, spatial and temporal patterns in fires within Kakadu National Park have been assessed at a whole of park scale.

Russell-Smith *et al.* (1997) and Gill *et al.* (2000) examined fire data for 1980 to 1996, with observations including the following:

- Only four percent of Kakadu National Park was not subject to fire during this time period, with an average of approximately 45 percent of the park burnt each year.
- Lowland savannah areas typically experience more widespread burning than plateau and floodplain areas, although burnt areas of the floodplain have significantly increased over this time period (refer Figure 3-12).
- An average of 25 percent of Kakadu National Park is burnt in the early dry season and 21 percent in the late dry season each year, with a pronounced shift over time from a fire regime dominated by late dry season fires up until the mid-1980s, to a fire regime dominated by early dry season fires.
- Lowland savannah areas were typically burnt three out of every five years, while plateau areas were burnt zero to four times over the 15 years and floodplain areas were burnt zero to three times over the 15 years.

It is important to note that these figures may not necessarily represent an ideal fire regime, but do reflect fire regimes at the time of listing.

The introduction of some exotic pasture grasses such as gamba grass *Andropogon gayanus*, mission grass *Pennisetum polystachion*, olive hymenachne *Hymenachne amplexicaulis* and para grass *Urochloa mutica* has resulted in changes to fire regimes within some areas of the Ramsar site (Director of National Parks 2007), as these species are able to better colonise bare areas following late dry season fire as compared to most native species, and consequently late dry season fires are avoided in certain areas. Additionally, these grasses (especially gamba grass and mission grass) increase the fuel load of fires and result in hotter burns, which can lead to the loss of tree cover (for example, NRETAS 2009).

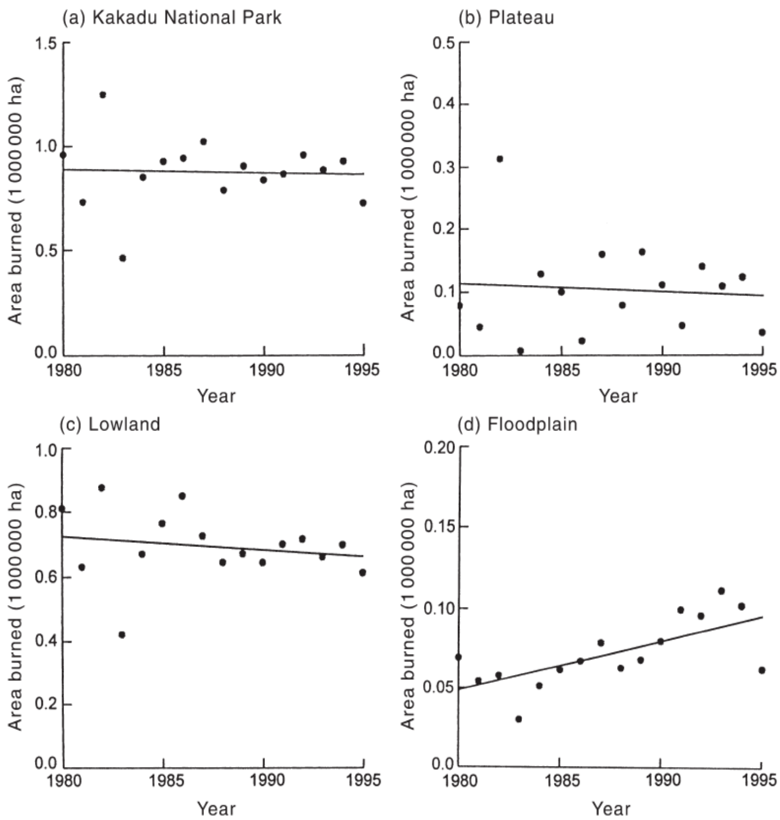


Figure 3-12 Areas burnt per year for Kakadu National Park (a) and various landscape types (b to d) (source: Gill *et al.* 2000)

3.5.3 P3 – Breeding of Waterbirds

Reasons for Selection as 'Critical'

Breeding is a critical life stage of species (as reflected in Criterion 2) that is essential in order to ensure the long-term persistence of populations that are fundamental to determining the site's ecological character.

Description

The most notable waterbird breeding colonies within the site are located within mangal communities of the major rivers and floodplain freshwater marshes. Breeding sites within mangroves are used by a variety of colonially nesting waterbirds (up to 12 species), though these multi-species colonies are typically dominated by egrets and herons (Chatto 2000). Chatto (2000) found that the breeding period for colonially nesting waterbirds (darters, cormorants, egrets, herons, spoonbills) extended throughout the year, generally beginning in November and ending in as late as October. The highest estimated annual usage of the five largest breeding colonies collectively amount to greater than 40 500 birds (Chatto 2000). Key sites for colonially breeding birds are associated with the downstream estuarine sections of both the East and South Alligator Rivers (southern and northern sides and within 15 kilometres of river mouth) (Chatto 2000). There are no seabird breeding colonies within the Ramsar site (Chatto 2001).

Floodplain wetlands are important for nesting waterbirds, although only five species breed in large numbers in the region (magpie geese *Anseranas semipalmata*, plumed whistling-duck *Dendrocygna eytoni*, wandering whistling-duck *Dendrocygna arcuata*, radjah shellduck *Tadorna radjah* and comb-crested jacana *Irediparra gallinacea*) (Bayliss and Yeomans 1990; Morton *et al.* 1991; Finlayson *et al.* 2006; Chatto 2006). Kakadu National Park's importance as waterbird breeding habitat is highlighted by the significant breeding aggregations of magpie geese throughout the floodplains of the site (up to 27 percent of the Northern Territory breeding population), with the South Alligator floodplains regarded as the third most important area of nesting habitat after the Mary-Adelaide and Daly River floodplains (Bayliss and Yeomans 1990). Waterbirds nest throughout floodplain wetlands during the wet season, and whilst variations in breeding effort (and location of higher density nesting) have been recorded between years, this is most likely to reflect local variations in rainfall (Frith and Davies 1961; Bayliss and Yeomans 1990). Important sites for nesting waterbirds include:

- South Alligator River upstream floodplains, including Boggy Plains (especially magpie geese) and Leichhardt's Lagoon (especially wandering whistling-duck).
- East Alligator River downstream floodplains, including the area around the junction of East Alligator River and Coopers Creek (especially radjah shelduck).
- East Alligator River upstream floodplains, including Magela and Nourlangie Plains (especially for magpie geese).

Waterbirds are more abundant as water levels drop during the dry season, with the bulk of species increasing in numbers during the dry season (Morton *et al.* 1991). These birds largely migrate from wetlands located to the south of the Ramsar site, including species such as the grey teal *Anas gracilis*, pink-eared duck *Malacorhynchus membranaceus*, hardhead *Aythya australis* and purple swamphen *Porphyrio porphyrio*. Magpie geese dominate the influx of waterbirds, concentrating around permanent and semi-permanent waterbodies during the dry season, and dispersing to the floodplains following significant rains at the start of the wet season (Whitehead 1998).

Patterns in Variability

There are no available data to describe nesting densities and reproductive success, either before or after declaration of the Ramsar site. Furthermore, although summary data are available from Birds Australia, raw waterbird count data are not publicly available. Refer to Section 3.2.7 for a general description of patterns in waterbird abundance.

3.5.4 P4 – Flatback Turtle Nesting

Reasons for Selection as 'Critical'

Breeding is a critical life stage of species (as reflected in Criterion 2) that is essential in order to ensure the long-term persistence of populations that are fundamental to determining the site's ecological character. The Ramsar site is considered critical in the context of maintaining the long-term viability of the flatback turtle *Natator depressus*, and underpins Critical Service 1 (see Section 3.6.1).

Description

Flatback turtle *Natator depressus* is listed as vulnerable under the EPBC Act. This marine turtle species is generally found feeding in subtidal coastal waters, unlike conditions found within the site boundaries. Field Island is an important nesting area (Schäuble *et al.* 2006). In particular, the beaches on the western side of the island are key breeding grounds, comprising the majority of suitable nesting habitat in the region (Winderlich 1998, Schäuble *et al.* 2006). Field Island and surrounding waters form one of six major nesting sites in Australia, identified in the Australian Government Recovery Plan for Marine Turtles as 'habitat critical to the survival of flatback turtles and is a key marine turtle-monitoring site within a national monitoring framework' (Environment Australia 2003).

In general, a female flatback turtle displays a strong fidelity to her chosen nesting beach, with most females returning to the same beach within a nesting season and in successive nesting seasons (Limpus 2007). In the Northern Territory, nesting density reaches a peak in July, although some nesting may occur year-round (Fry in Limpus 2007). This dry season peak of nesting activity may be adaptive to protect the eggs from the high sand temperatures that occur in the wet season (Guinea in Limpus 2007).

Patterns in Variability

The key parameters describing this component are: (i) turtle nesting intensity indicators (number of nesting attempts per night or individuals nesting per survey night) and (ii) clutch size and clutch success. Turtle nesting patterns have been (and continue to be) monitored at Field Island annually. Schäuble *et al.* (2006) reported monitoring program results for these (and other) indicators on an annual basis between 1990 and 2001 (refer Figure 3-13), which is post-listing (Stage II 1989). Note that there are no data describing breeding rates prior to site listing.

Figure 3-13 shows that the mean number of nesting attempts has remained relatively consistent over time, whereas the maximum number of nesting attempts per night has tended to increase over time. The number of nesting individuals was variable over time, which may reflect differences in sampling effort, timing of surveys relative to the peak nesting period and changes in nesting intensity. The mean number of eggs per clutch was 52.4 (± 8.6 SD). Schäuble *et al.* (2006) also found that breeding success was high, with a mean clutch hatchling rate of 88 percent (± 17 percent SD) and an emergence success rate of 64 percent (± 32 SD).

This component is underpinned by the following processes:

- coastal geomorphological and oceanographic processes that maintain the sandy beaches
- connectivity between marine and dune habitats, and
- absence of disturbance by humans and feral predators.

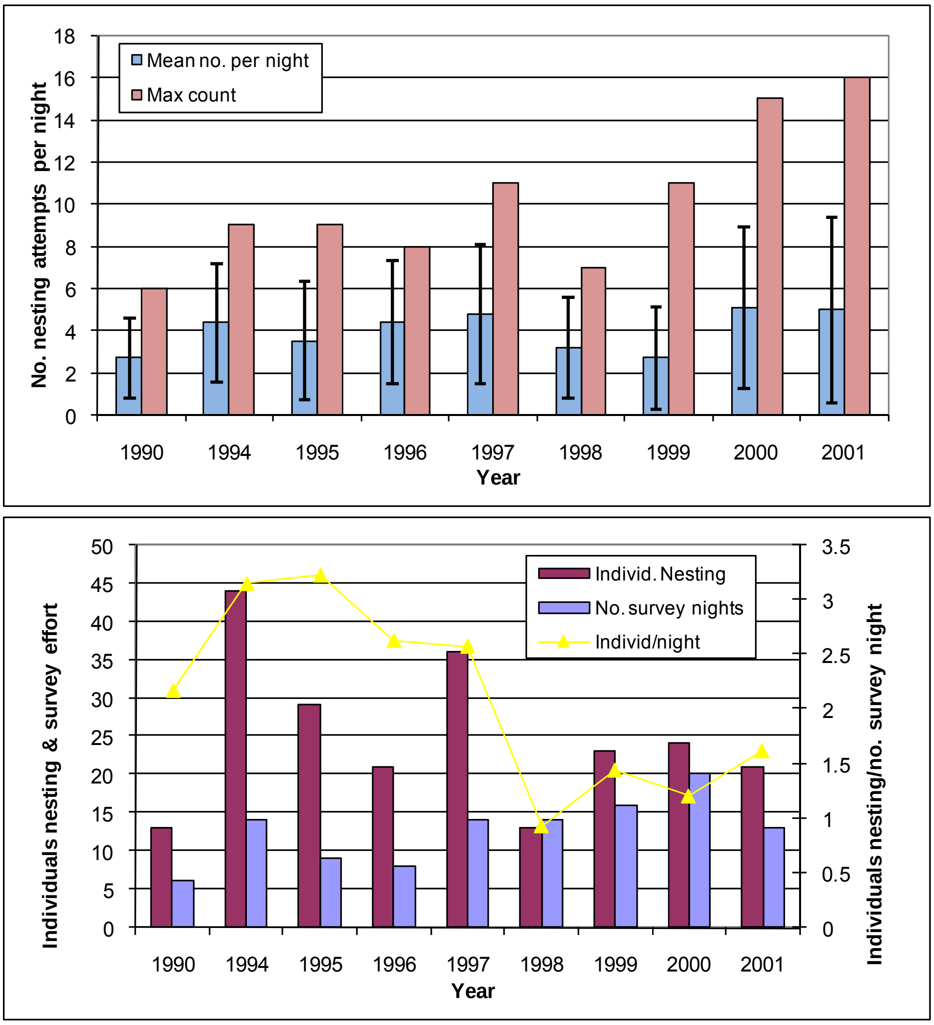


Figure 3-13 Mean (error bars = SD) and maximum number of nesting attempts per night, and numbers of nesting individuals per survey night recorded at Field Island (1990-2001) (source: Schäuble *et al.* 2006)

3.6 Supporting Processes

The supporting processes outlined below are considered to be important or noteworthy in the context of maintaining the character of the site, but are not considered to represent critical processes in the context of the considerations outlined in section 3.1.1 of this report. In this context:

- Supporting processes may operate over broad spatial scales and are not considered likely to be fundamentally altered by activities within the site.
- Some supporting processes are already partially covered by other critical components, processes or services/benefits.
- The supporting processes, while not critical, are important to wetland functioning and are noteworthy in this regard.

3.6.1 Climate

3.6.1.1 Seasonal Cycles

Climate conditions for the Alligator Rivers Region, have been described by Saynor *et al.* (2000 and references therein). In general, the climate of the Alligator Rivers Region can be defined as wet-dry tropical with a wet season duration of four-and-a-half to seven months. Humidity is generally highest between January and March with mean relative humidity (at 9 am) greater than 80 percent. Temperatures at Jabiru are high throughout the year (Figure 3-14), with temperatures higher than 30 degrees Celsius observed on average more than 320 days per year between 1971 and 2009. Annual mean minimum and maximum temperatures were 22.5 degrees Celsius and 34.2 degrees Celsius, respectively. The highest temperatures are generally recorded from September to October while lowest temperatures usually occur from June to August (Figure 3-14). Average annual maximum temperatures in the Northern Territory have increased by about 0.12 degrees Celsius per decade since 1950 together with an increase in frequency of extremely warm days and nights and a concurrent decrease of extremely cool days and nights (Hennessy *et al.* 2004). Greater warming was observed in May to October compared to November to April.

The warmer wet season is marked by monsoonal depressions bringing heavy rain and occasional tropical cyclones to the area. Over 90 percent of the average rainfall occurs during the wet season between November and March (Figure 3-15) with mean annual rainfall ranging from approximately 1300 millimetres in the south to 1500 millimetres at Jabiru. Little or no rain occurs during the cooler dry season extending from May to September (Figure 3-15). Potential evaporation (2400 – 2700 millimetres per year) exceeds rainfall in most years (Saynor *et al.* 2000).

The Northern Territory has become wetter between 1950 and 2002 with average rainfall rising 35.7 millimetres per decade for November to April and falling 0.4 millimetres per decade for April-October (Hennessy *et al.* 2004). Particularly strong rainfall periods were observed in the mid-1970's and in 1999-2000 and the highest rainfall on record at Jabiru Airport was observed during the wet season of 2007 (Hennessy *et al.* 2004, Bureau of Meteorology website 2009).

Winds are predominantly from the south-east and east between April and September, whereas winds are more variable with an often strong westerly and northerly component from November to February.

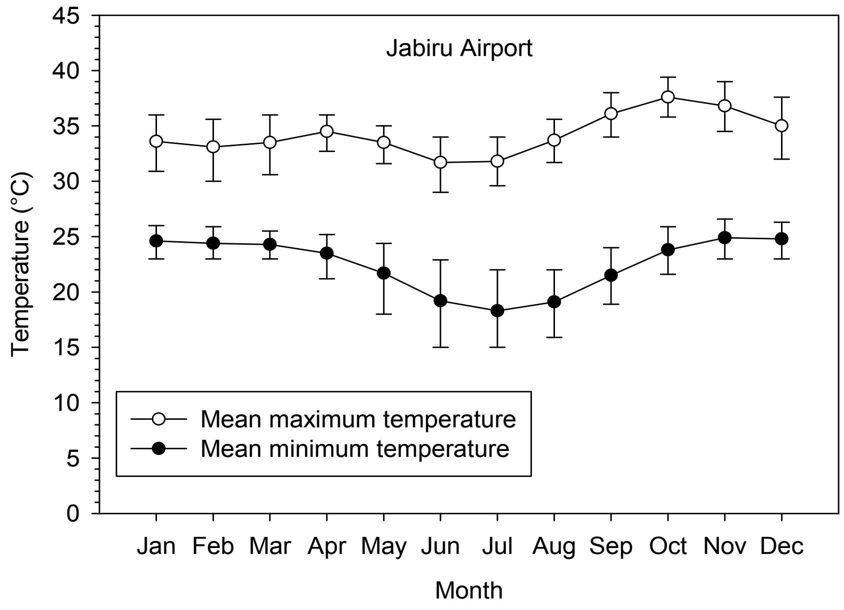


Figure 3-14 Mean maximum and minimum temperature at Jabiru Airport between 1971 and 2009. Upper and lower error bars denote the 90th and 10th percentiles (source: Bureau of Meteorology unpublished data)

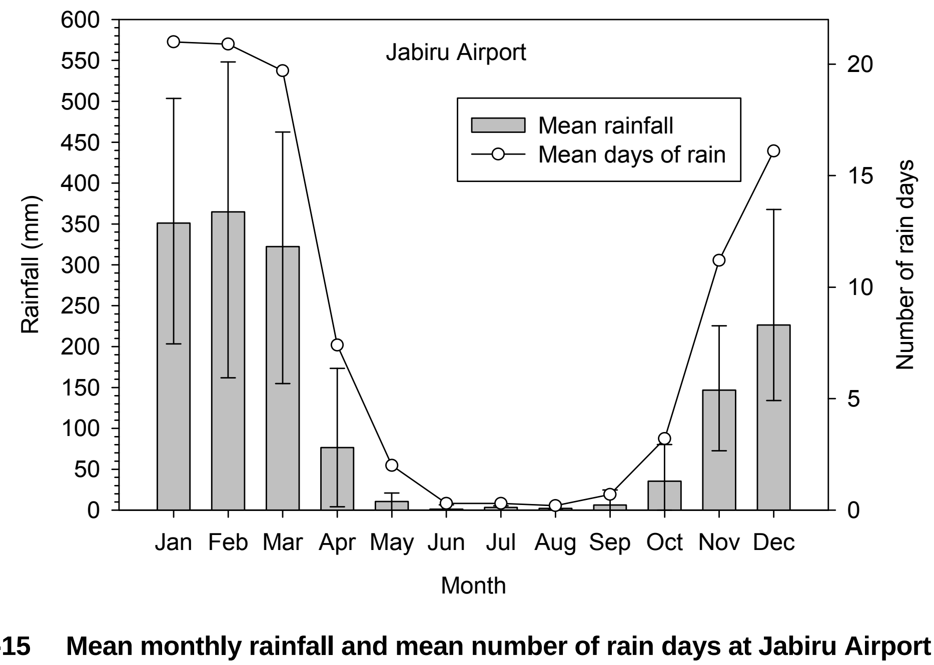


Figure 3-15 Mean monthly rainfall and mean number of rain days at Jabiru Airport between 1971 and 2009. Upper and lower error bars denote the 90th and 10th percentiles (source: Bureau of Meteorology unpublished data)

3.6.1.2 Long-term Cycles

The El Niño Southern Oscillation (ENSO) modulates the behaviour of the monsoon and frequency of cyclones experienced (Hennessy *et al.* 2004, Wasson *et al.* in prep.). The El Niño phase tends to suppress monsoon and cyclone activity over the Northern Territory, while the La Niña phase tends to enhance this activity. Hence, dry periods tend to be El Niño years, whereas the wet periods are usually La Niña years.

However, further climate variability on longer, decadal time scales was suggested by Power *et al.* (1999). In particular, the Inter-decadal Pacific Oscillation (IPO) has been shown to be associated with decadal climate variability over parts of the Pacific Basin, and to modulate interannual ENSO-related climate variability over Australia (Salinger *et al.* 2001). Accordingly, Wasson *et al.* (in prep.) noted an approximate 20-year decadal variation in rainfall and flow for the Magela Creek (18 years) and Katherine River (22 years) catchments. The decadal variations in rainfall and flow were essentially in-phase. Bayliss *et al.* (2008) also noted that other major rivers across the "Top End" of the Northern Territory exhibit 20-25 year periodicities in flow volume.

Such long term decadal periodicities in rainfall and flow may have important implications for the biology in the area. This was demonstrated by Bayliss *et al.* (2006, 2008) who showed that magpie geese *Anseranas semipalmata* across the Northern Territory exhibited approximately 20 year population cycles that were coupled to similar and generally coherent periodicities in flow of the Katherine River, Daly River and Magela Creek (refer Figure 3-16). The authors noted an average response time lag of three to five years between river flow and magpie goose numbers.

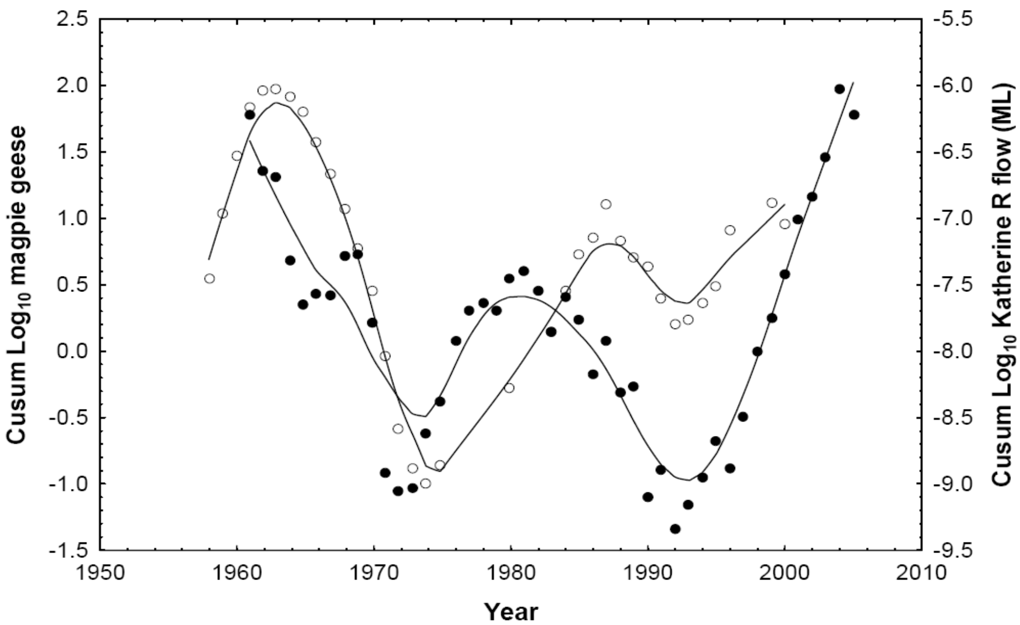


Figure 3-16 Cusum plots (cumulative sum of mean deviations) of magpie goose numbers (white symbols) in the Northern Territory and Katherine River flow (black symbols) Figure reproduced from Bayliss *et al.* (2008)

3.6.1.3 Extreme Climatic Events

As would be expected for a tropical locality, the Ramsar site experiences severe weather events in the form of cyclones and the associated strong winds, heavy rains and destruction. An average of eight to ten cyclones form annually between November and May in tropical northern Australia (Holland 1984). Monthly totals of tropical cyclones in the Northern Territory over the last four decades are shown in Figure 3-17.

A recent example of an extreme climatic event is a tornado that swept through the National Park in March 2007, with winds of between 230 and 270 kilometres per hour that left a three kilometre path of snapped or uprooted trees and damaged caravans near the Mary River Ranger Station, and record-breaking rainfall that flooded the Oenpelli and Adelaide River areas[3].

It is highly likely that the frequency and severity of extreme climatic events will increase as a result of climate change (see Section 5.3 and BMT WBM 2010).

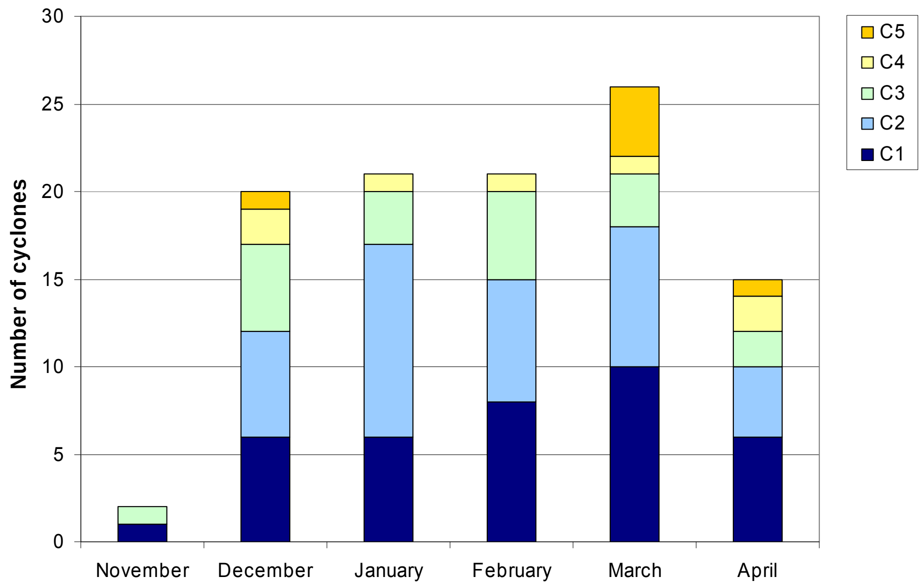


Figure 3-17 Total number of tropical cyclones in the Northern Territory between 1963 and 2006 by category, where C5 is the most destructive category (source: Bureau of Meteorology)

3.6.2 Geology and Geomorphology

3.6.2.1 Geology

Landscape features within Kakadu National Park cover over 2000 million years of geological evolutionary history (Press *et al.* 1995b). The Kakadu National Park region is situated in the eastern part of a major geological structure known as the Pine Creek Geosyncline, which is the main geological structure of the region (Commonwealth of Australia 1988, Press *et al.* 1995b). The region

[3] See http://www.bom.gov.au/announcements/media_releases/nt/20070320.shtml

provides a favourable setting for mineral deposits of economic significance, particularly in the eastern part.

In the historic Stage I and Stage II areas of Kakadu National Park, the mineralisation is mainly located in a rock formation known as the Cahill Formation, which includes the Ranger, Jabiluka and Koongarra uranium deposits. The Cahill Formation is considered a major uranium deposit on a world scale, but exploration indicated the presence of a range of metals, including gold (Commonwealth of Australia 1988). Mineralisation in the Stage III area of the region is primarily located in a series of rock formations known as the El Sherana Group and includes gold, platinum and minor uranium deposits.

While the area is regarded as highly prospective for mineral exploration, the rock formations are often masked by younger overlying sequences, including the sandstones forming the Arnhem Land escarpment. The sandstone formations of the Arnhem Land escarpment date back about 1700 million years and can be up to 300 metres in depth. Erosion of the younger rocks has resulted in a deep soil cover over much of the region, which is about 40 metres deep. However, the tectonic stability and antiquity of the landscape resulted in deep weathering of the rocks forming strongly leached and relatively infertile soils (Press *et al.* 1995b). Together with the pronounced rainfall seasonality, this has markedly influenced flora and fauna development in the region.

In contrast, the extensive coastal and riverine alluvial plains are of recent origin, often dating back no more than a few thousand years (Press *et al.* 1995b). These recent landforms are a result of sediment deposition in drowned river valleys associated with sea level stabilisation at about its present level ca. 6000 years ago. Hence, the deeper saline sediments underlying the floodplains are overlain by brackish, organic-rich, acidic soils, which support the freshwater wetlands (Press *et al.* 1995b).

3.6.2.2 Geomorphology

Rivers in the Northern Territory have several morphological phases and move from one phase to another as they respond to tidal pressure and seasonal freshwater runoff (Chappell and Woodroffe 1984, Petty *et al.* 2005). Different longitudinal regions of the rivers will exhibit distinct morphological features depending on the state of development of the particular region (Figure 3-18).

Because the flooding tide has higher peak velocities than the ebbing tide, a much higher sediment load can be transported during floods. This sediment is deposited along the tidal channels, gradually forming mud levees at the upper estuary (refer Figure 3-18). These levees contain the channel, prevent further saltwater penetration and impound freshwater in large wetlands (Petty *et al.* 2005). During the course of the dry season, the salinity of these wetlands will increase, and in some areas will become quite brackish.

The annual freshwater impoundment maintains the low salinity soil surface of the wetlands, overlying a highly saline subsoil region. Without the impoundment, subsoil salt may emerge resulting in widespread die-off of freshwater species.

Some notable morphological features formed in recent times (several thousand years) include palaeo-channels, dendritic channels and billabongs, which generally form in palaeo-channels. Palaeo-channels are remnant tidal channels that were active during the mid-Holocene, and have since been partially or completely infilled by deposition of tidal sediments (Woodroffe and Mulrennan 1993). They are apparent as billabongs, freshwater swamps and wetlands. As palaeo-channels are some of the lowest-lying topography within a coastal floodplain, they are particularly vulnerable to saltwater intrusion. The intrusion of saltwater can result in the death of freshwater vegetation and development of bare surfaces susceptible to aeolian (wind blown) erosion.

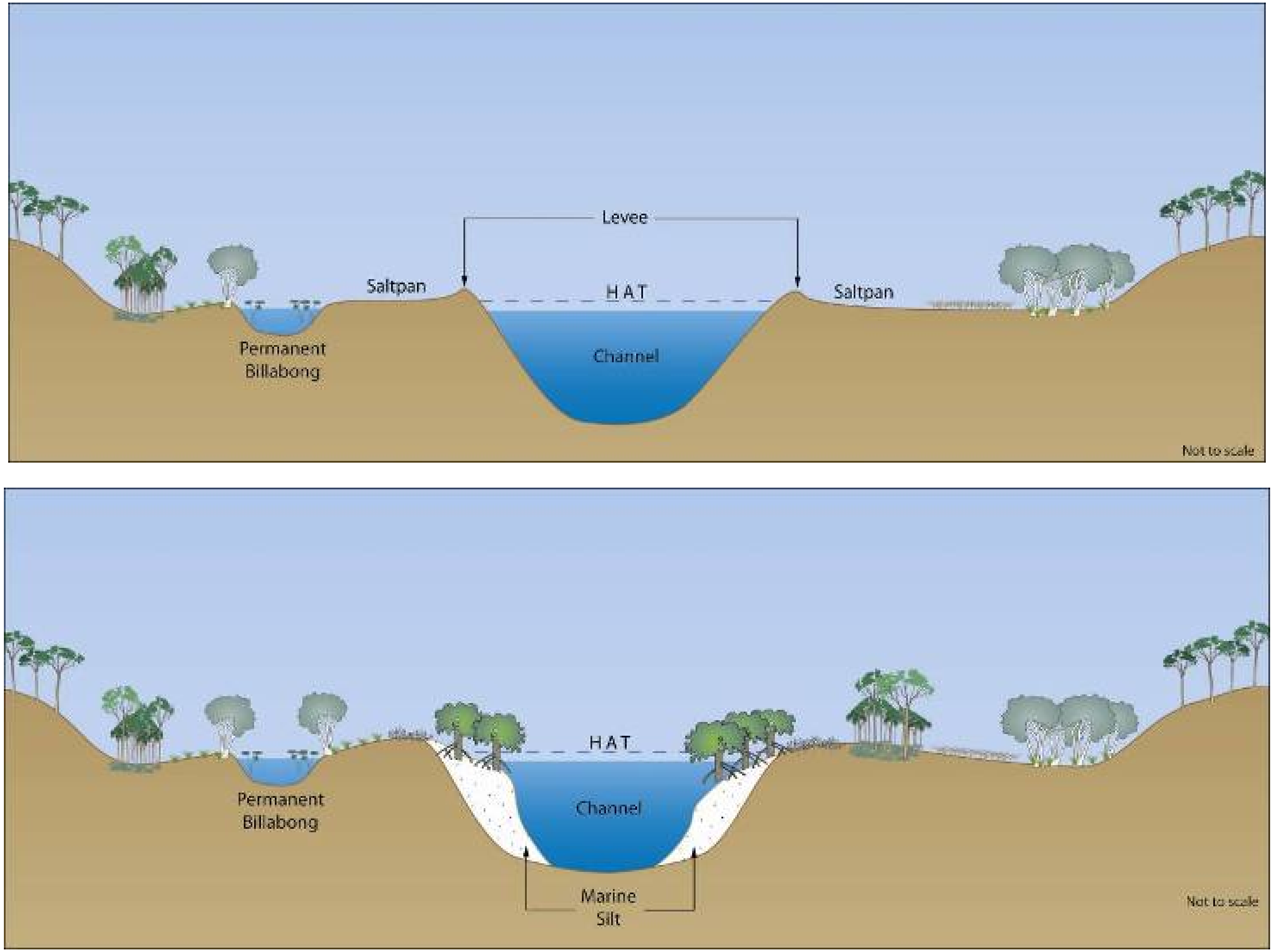


Figure 3-18 Typical cross section of (top) upper estuary and (bottom) lower estuary

3.6.3 Tidal Hydraulics

Tidal processes of rivers in the region have been described in detail by Vertessy (1990) and are summarised here. In the South Alligator River, the largest river within the site, the tidal component extends from the mouth in Van Diemen Gulf to just downstream of Yellow Water for a distance of about 105 kilometres. The maximum range in tide height at the mouth is 5.8 metres. Comparable values at other stations along the South Alligator River indicate that there is only minor attenuation of tidal amplitude with distance from the sea over most of the river.

Tides are moderately asymmetric at the mouth (that is, not equal in duration), with spring tide ebb and flood durations of approximately 415 and 320 minutes and neap tide ebb and flood durations of 410 and 325 minutes, respectively. Ebb/flood duration and velocity become increasingly asymmetric with distance from the mouth, with flood tides having shorter durations and higher peak velocities. In the mid and upstream reaches flood current velocities approach two metres per second, whereas ebb current velocities rarely exceed one metre per second. Due to the shorter flood tide with a steeper gradient, the flood tide can carry a much higher sediment load than the ebb tide, consequently resulting in sediment transported up the river.

Storm surges induced by cyclonic winds in the order of four metres are another major influence on water levels at the mouth of the South Alligator River. This increase in water level is added to the existing tide level at the time of the cyclone to give a combined storm tide level. Because of the random nature of the combination of tide and storm surge, however, this level is not necessarily above the Highest Astronomical Tide level (HAT) for the river. With regards to salinity, flows experienced during the wet season are sufficient to flush the tidal channel to fresh water levels over almost the full length of the estuary (see BMT WBM 2010).

3.6.4 Water Quality

Description and Patterns in Variability

Only limited water quality data are available from the Alligator Rivers Region. While water quality data are available from a number of stations within the Magela Creek catchment in the eastern part of Kakadu National Park, only little information on water quality is available from the western and middle sections of the site (Figure 3-19). Most of the data were collected between the early 1970s and mid-1980s. Since this time, there has been some intensive monitoring in selected waterways in the Magela floodplain; however there has been comparatively little water quality data collection elsewhere in the site.

Freshwaters

There are no regional or local water quality guidelines for the Ramsar site. Therefore, available water quality data have been compared with ANZECC/ARMCANZ (2000) guidelines values. However, it is to be noted that the ANZECC guidelines are not based on regional reference values and consequently any non-conformity with the ANZECC guidelines does not necessarily represent a change in ecological character (refer Section 4.3).

Table 3-7 shows a comparison of the 20th and 80th percentiles of available water quality data with ANZECC/ARMCANZ (2000) guideline values. It is noted from this data that the water in streams of the region are fairly acidic, with the 20th percentile of pH often below the ANZECC guideline value. Relatively high acidity is especially notable for stations along the Magela Creek Plain, characterised by acid sulfate soils and where extremely acidic "first flushes" after the dry season are commonly observed events (Willett 2008).

While no information on nutrient concentrations is available for the upland stations of the region, the 90th percentile of nutrient concentrations often exceeded ANZECC guideline values at the lowland stations (Table 3-7). Notably high 80th percentile nutrient concentrations were recorded at stations within the Magela Creek catchment, a region characterised by a number of backflow, channel and flood plain billabongs (Hart and McGregor 1980). Concurrent with increased nutrient concentrations, elevated 80th percentiles of conductivity, turbidity and chlorophyll *a* and relatively low 20th percentiles of dissolved oxygen were recorded at these stations (refer Table 3-7). In line with these findings, Hart and McGregor (1980) showed that billabong waters in the Magela Creek catchment had elevated conductivity, turbidity, nutrient and chlorophyll *a* concentrations at the end of the dry season. A significant improvement in water quality with commencement of the wet season and flushing of the billabongs was noted. The authors also demonstrated that billabong waters became significantly depleted in dissolved oxygen when mixing of the water column did not occur for several days under certain conditions.

In support of these results, Figure 3-20 shows the seasonality in water quality parameters at a site within the Magela Creek catchment. Conductivity is generally higher around the end of the dry season, concurrent with an increase in nutrient concentrations. Based on these results, evapo-concentration is the likely mechanism that leads to the observed increase in nutrient and ion concentrations in the Magela Creek catchment. As a result of increased nutrient supply, chlorophyll concentrations may increase within the billabongs. With the onset of wet season flushing, nutrient concentrations are diluted as demonstrated by the concurrent decrease in conductivity values (Figure 3-20).

Townsend and Douglas (2000) investigated the effect of different fire regimes on stream water quality in Kakadu National Park in three Eucalypt-dominated open-forest catchments. The authors found that fires lit in the late dry season reduced canopy cover, riparian tree density and increased the amounts of bare ground, thereby increasing erosion. Accordingly, Townsend and Douglas (2000) found that storm runoff concentrations of suspended sediments, iron and manganese were two to five times higher after late dry season fires. In contrast, fires lit during the early dry season had an overall negligible effect on wet season stream water quality, except possibly for a small increase in nitrogen concentrations and loads (Townsend and Douglas 2004).

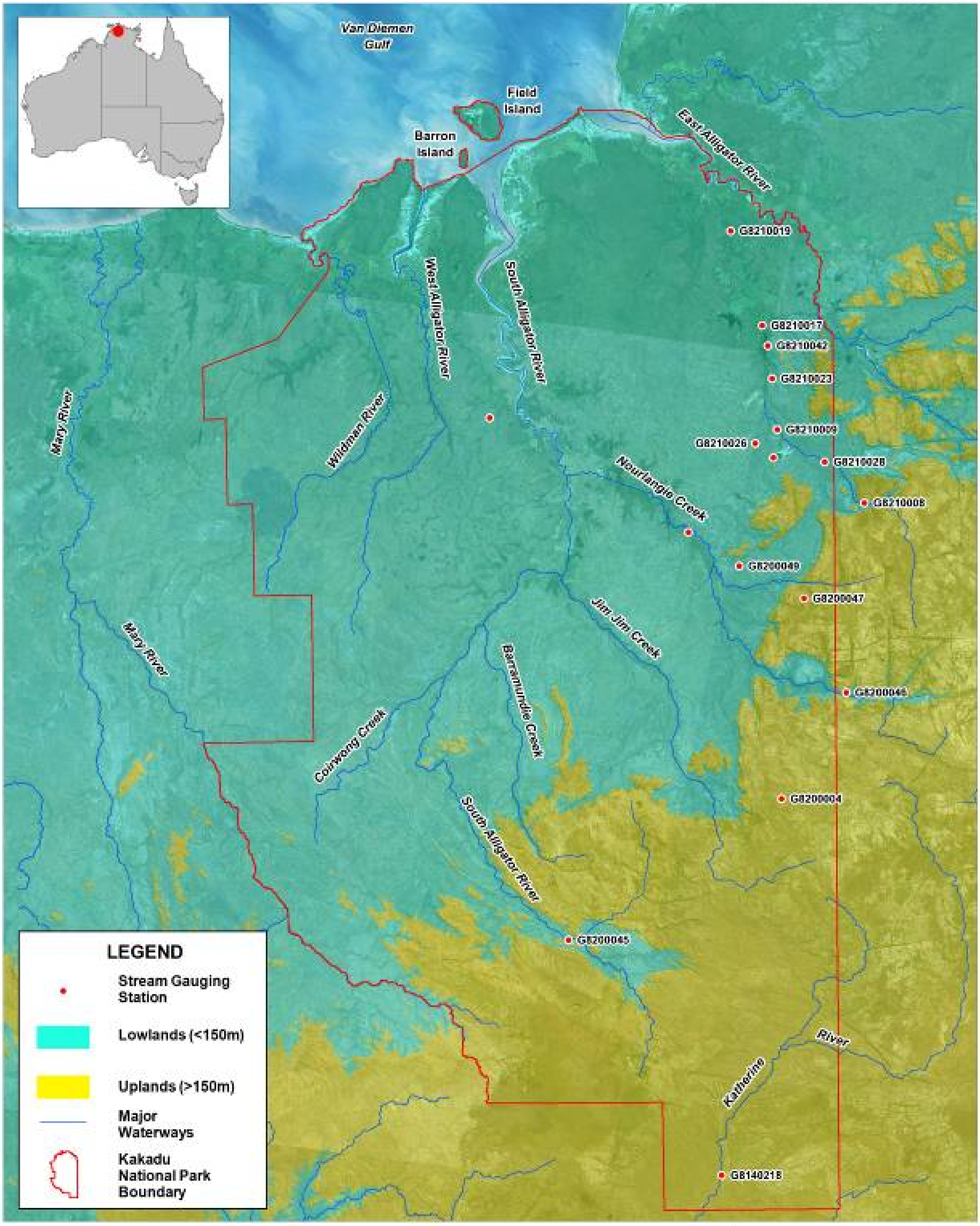
Estuarine and Marine Waters

There are no available empirical data describing the water quality of estuarine and marine waters. This is considered an important information gap.

Table 3-7 Water quality data (80th percentiles; 20th and 80th percentiles for dissolved oxygen and pH) from gauging stations in the Kakadu National Park catchment and comparison to ANZECC guideline values. Values in red denote exceedance of guideline limits. (source: NRETAS unpublished data)

Location		Data period	Water temp. °C	Conductivity µS cm^{-1}	pH	Turbidity NTU	Diss. Oxygen % saturation	Total Nitrogen mg L^{-1}	Oxidised N mg L^{-1}	Ammonia mg L^{-1}	Total Phosphorus mg L^{-1}	Chlorophyll a µg L^{-1}
Upland stations >150m CD												
Guideline	ANZECC Upland			250	6.0 - 7.5	2 - 15	90 - 120	0.15	0.03	0.006	0.01	N/A
G8140218	Katherine River at Mt Ebsworth	1967 - 1977		34 *	6.3 - 6.6 *							
G8200004	Jim Jim Creek at Above Five Sisters	1972 - 1977		25.8 *	5.4 - 6.1 *							
G8200045	South Alligator River at El Sherana	1963 - 1991	26.6	110 *	6.6 - 7.4 *							
G8200046	Deaf Adder Creek at Coljon	1972 - 1986	30.3	20	5.8 - 6.5	17						
G8200047	Hickey Creek at Sawcut Gorge	1972 - 1986	29.4	14	5.8 - 6.1	3						
Lowland stations < 150m CD												
Guideline	ANZECC Lowland			250	6.0 - 8.0	2 - 15	85 - 120	0.3	0.005	0.01	0.01	5
G8200049	Koongarra Creek at Near Nourlangie Rock	1973 - 1986	32.1	24	5.5 - 6.6	10	86 - 94	0.45	0.011	0.010	0.010	1.0
G8200083	Catchment G at Kapalga Research	1993 - 1995		26 *	6.1 - 6.6 *				0.020		0.020	
G8200112	Nourlangie Creek at Kakadu Highway	1971 - 1985	31.0	39	5.3 - 6.6	8	69 - 87	0.55	0.020	0.020	0.015	2.8
G8210008	Magela Creek at Bowerbird Waterhole	1971 - 1982	31.0	25	5.3 - 6.3	8	81 - 94	0.29	0.022	0.010	0.010	1.0
G8210009	Magela Creek at downstream Jabiru	1971 - 1987	30.0	20	5.4 - 6.3	14	80 - 95	0.33	0.050	0.014	0.010	1.0
G8210012	Gulungul Creek at Georgetown crossing	1972 - 1977		23 *	5.9 - 6.3 *							
G8210017	Magela Creek Plains at Jabiluka Billabong	1972 - 1987	32.0	88	5.1 - 6.1	47	66 - 100	1.36	0.474	0.220	0.015	6.0
G8210019	Magela Plains at outflow main channel	1975 - 1987	31.6	246	5.5 - 6.5	63	26 - 87	0.86	0.066	0.030	0.016	7.6
G8210023	Magela Creek Plains at Island Billabong	1972 - 1987	32.0	37	5.1 - 5.9	11	45 - 83	0.45	0.030	0.016	0.015	8.0
G8210026	Baralil Creek at Arnhem Highway	1978 - 1987	30.0	78	5.7 - 6.8	21	50 - 90	0.70	0.030	0.020	0.020	1.8
G8210028	Magela Creek at Arnhem Border site	1979 - 1987	30.0	26	5.3 - 6.3	14	61 - 90	0.35	0.050	0.015	0.010	1.0
G8210042	Magela Creek at Mine Valley	1976 - 1985	32.0	203	4.9 - 6.4	42	47 - 106					

Lowland stations: less than150 metres; upland stations: greater than 150 metres or directly adjacent to 150 metres contour (refer Figure 3-19) Note that % dissolved oxygen saturation values were calculated according to Weiss (1970) from measured concentrations in mg/L and the median temperature at the respective sites (salinity = freshwater)



Title: **Water Quality Gauging Stations in Kakadu National Park**

Figure: 3-19

Rev: A

N 0 20 40km Approx. Scale

BMT WBM www.bmtwbm.com.au

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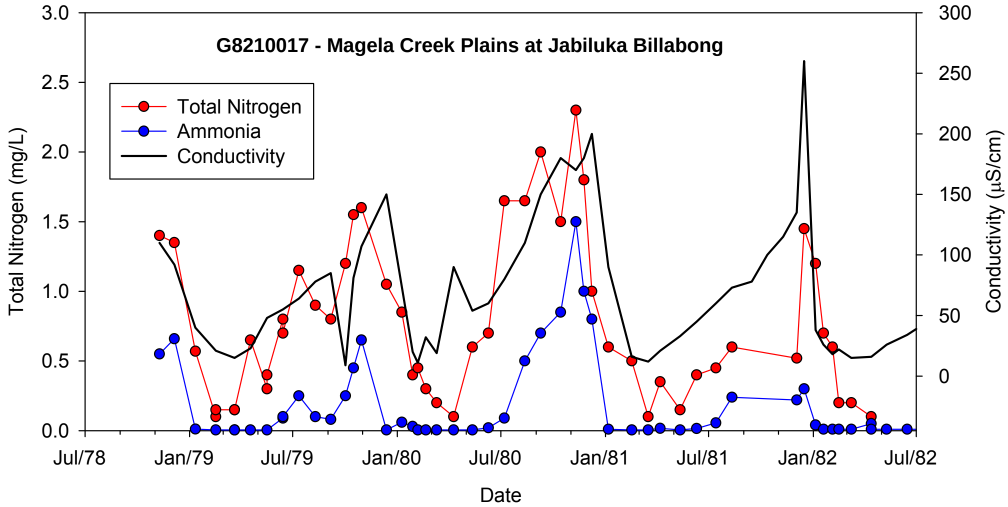


Figure 3-20 Seasonal pattern of conductivity and nutrient concentrations (total nitrogen and ammonia) at gauging station G8210017

3.6.5 Groundwater

NRETA has produced an overall map of the groundwater resources of the Northern Territory (refer Ticknell 2008). Aquifer types within Kakadu National Park have been classified as the following as shown in Figure 3-21:

- *Fractures and Weathered Rocks* with local scale aquifers which occur broadly across the site in the floodplain and catchment areas.
- *Fractures and Weathered Rocks* with minor groundwater resources and local scale aquifers which occur over the majority of the escarpment Stone Country.
- *Fractured and Karstic Rocks* with intermediate to local scale aquifers which occur over small areas in the north-eastern and southern parts of the escarpment.
- *Sedimentary Rocks* with intergranular porosity with regional to local scale aquifers which occur along the lower reaches of the East Alligator River and within an area of the south-west of the site.

The scale of aquifers as mentioned above refers to distance over which groundwater flows through the aquifer from recharge to discharge areas. Specifically, local scale indicates less than five kilometres, intermediate scale refers to distances of five to 50 kilometres, and regional scale refers to greater than 50 kilometres.

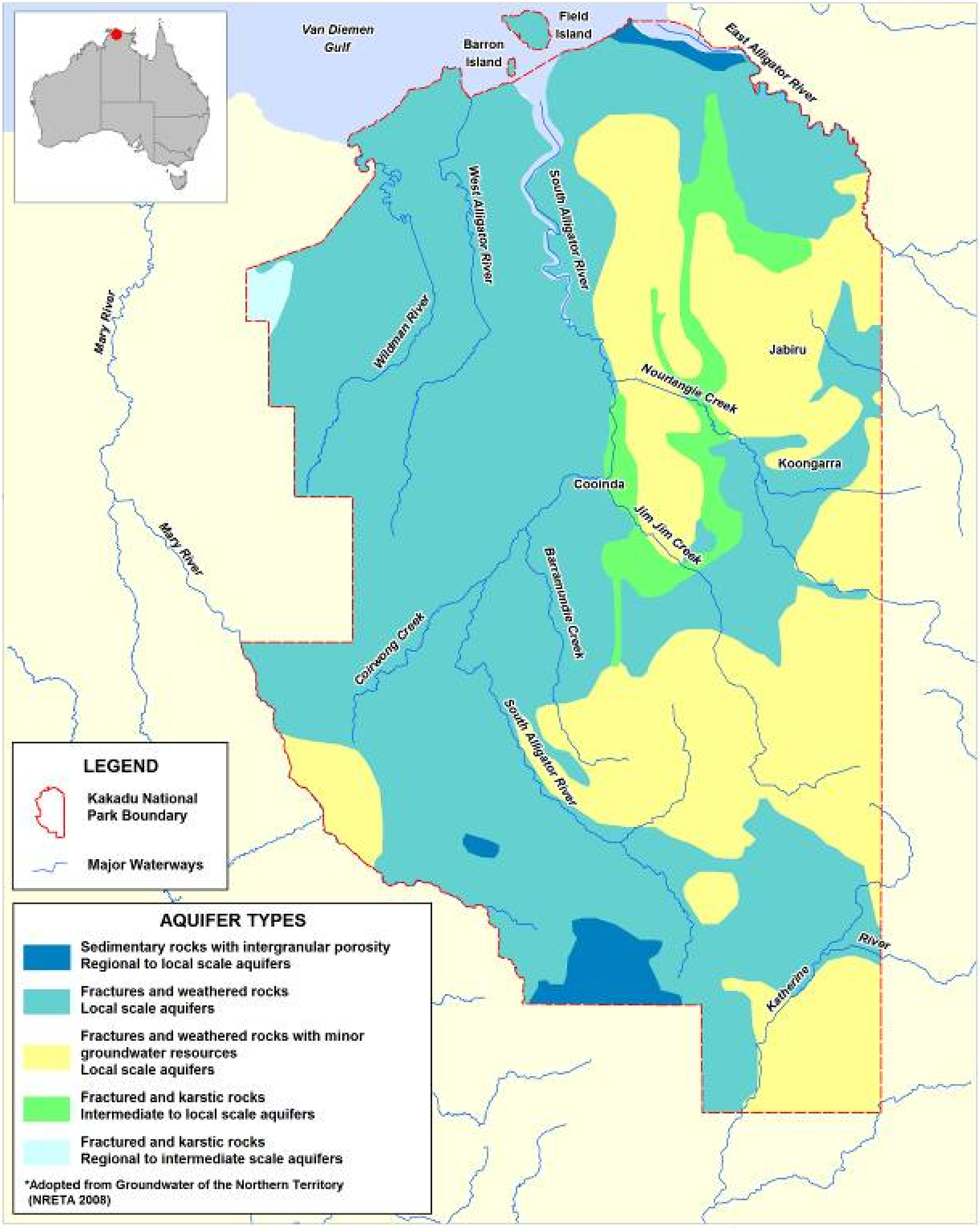
As outlined previously in the discussion of wetland types, Kakadu National Park has several groundwater-dependant freshwater springs that are predominantly situated in the northern-eastern portion of the Stone Country between the South and East Alligator Rivers. A number of seeps have also been identified by NRETA further south in the Stone Country but no empirical data on their exact location are available. Such features would likely correspond with the larger scale aquifers present in these environments.

Groundwater usually discharges at low lying points in the landscape. It can take the form of individual springs or as diffuse seepage into streams. Dry season flows into the river systems of the Northern Territory are maintained through groundwater discharge particularly in karstic systems where there are more substantial groundwater resources present. However, as these karst systems are very limited within the Ramsar site, it is likely that the contribution of groundwater to surface water flows is minor for the mid and lower reaches of Kakadu's major river systems and/or is highly localised in relation to major billabongs. Finlayson *et al.* (2006) indicates that in the floodplain areas, groundwater levels can fall between two to four metres during the Dry Season.

Groundwater discharge may play a much more important role in the context of the upper reaches of the river systems and for permanent and ephemeral streams located in the upstream and escarpment areas but no studies to date have assessed the interaction between groundwater and surface water in these environments and the relative contribution of groundwater flows during the dry season.

Groundwater discharge can also occur through trees and riparian vegetation tapping directly into shallow water aquifers. This process is identified as being very significant in the southern parts of the Northern Territory by Ticknell (2008), but is not identified as a dominant process in the northern, coastal areas of the Territory such as Kakadu. The extent to which this process occurs in the site is also an information gap.

While there have not been any comprehensive studies of groundwater for the Park to date, there have been site-specific studies of the mineral lease area in the context of movement of potential contaminants from Jabiluka mine tailings by groundwater flow toward the park (refer Kalf and Dudgeon 1999). In this study groundwater flows from the mine site into the Magela floodplain was modelled to predict the concentrations of contaminants to be expected along the flow paths. In terms of groundwater movement, the findings of the study noted that there were weak upward components of groundwater flow both east and west of the mine and it was considered that any such flow which reaches the shallow alluvial or weathered rock zone would be diluted and flushed away by the annual wet season surface flows.



Title:
Groundwater within Kakadu National Park (source: Ticknell 2008)

Figure: 3-21

Rev: A

BMT WBM endeavours to ensure that the information provided in this map is correct at the time of publication. BMT WBM does not warrant, guarantee or make representations regarding the currency and accuracy of information contained in this map.

N

0 20 40km

Approx. Scale

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Filepath : I:\B17399_I_GML Kakadu Ramsar GWF\DRG\ECO_008_100223_ Groundwater_Aquifers.wor

This is consistent with general observations about the water quality of groundwater resources of the Northern Territory including Kakadu, which are characterised by NRETA (2008) as being generally of low salinity as a result of high rainfall, high recharge rates and higher through-flow of groundwater (due to small aquifers) compared to more arid zones in the south.

3.6.6 General Ecosystem / Biological Processes

3.6.6.1 Nutrient Cycling

Information on nutrient cycling processes within Kakadu National Park is scarce. In one study addressing nutrient cycling in the broader region, Cook (1994) investigated the effect of fires on nutrient fluxes in the tropical savannah at Kapalga, Kakadu National Park. The magnitude of nutrient fluxes due to fires was greatest in forest communities, where grassy fuel loads were high. Up to 94 percent of measured nutrients were transferred to the atmosphere during the fires. While nutrients transferred to the atmosphere as entrained ash settled within several kilometres of the fires, nutrients transferred in gaseous forms, such as nitrogen, are lost from the system. Cook (1994) noted that the losses of nitrogen greatly exceeded the inputs through rainfall and re-deposition of ash. Furthermore, nitrogen fixation was found to be of insufficient magnitude to replace the lost nitrogen, indicating that annual burning may deplete nitrogen reserves in Kakadu National Park savannas.

3.6.6.2 Aquatic Foodwebs

Similar to other areas throughout Australia's wet-dry tropics, aquatic food webs in the Kakadu National Park region are closely linked with seasonal hydrology. Douglas *et al.* (2005) provide a review and conceptual model of river and wetland food webs in Australia's wet-dry tropics, using numerous examples from Kakadu National Park. Based on this review, the aquatic food webs and associated ecosystem processes in Kakadu National Park are assumed to be underpinned by five general principles, as outlined below. Refer to Douglas *et al.* (2005) for further information.

1. *Seasonal hydrology is a strong driver of ecosystem processes and food web structure*. Food web structure is highly dynamic throughout the year, with the seasonal hydrological cycle (a reliable flood-pulse) driving the supply of carbon and nutrients that support food webs. The seasonal variation in water levels drives major changes in habitat availability, primary productivity and, consequently, the abundance and composition of consumer communities.

2. *Hydrological connectivity is largely intact and supports important terrestrial-aquatic food web subsidies*. The food webs of tropical rivers are characterised by very strong hydrological connections, exchanges between terrestrial and aquatic ecosystems, as well as between productive habitats like floodplains and less productive rivers habitats. Additionally, the flow regime is a key driver of exchanges between organisms and their food resources. For example, at the end of the wet season, aquatic fauna migrating from the floodplain to dry-season refuges transfer their assimilated aquatic production to these upstream rivers or billabongs. Similarly, terrestrial riparian inputs of fruit, insects, leaves and other organic debris are thought to be important contributors to the aquatic food web. The very strong aquatic linkages and floodplain connectivity are largely due to the relatively undisturbed hydrological condition of the rivers in the region (for example, lack of major waterway barriers and agriculture) and the high level of intact riparian and floodplain vegetation.

3. *River and wetland food webs are strongly dependent on algal production*. Relative to other aquatic plants and terrestrial inputs, benthic (and epiphytic) algae are typically the major source of organic carbon supporting consumers and sustaining the food webs. For instance, work in the floodplain wetlands of the East Alligator River has shown that most of the biomass carbon and nitrogen of fish and aquatic invertebrates was derived from epiphytic algae.

4. *A few common macro-consumer species have a strong influence on benthic food webs*. Tropical aquatic food webs are typically dominated by a small number of relatively large-bodied consumers, such as fish and shrimp, which have a strong influence on benthic sediments, detritus, nutrient demand, and algal and invertebrate communities. The catfish *Neosiluris ater* and the shrimp *Macrobrachium bellatum* are species that have been shown to have such an influence elsewhere in the Northern Territory, although the strengths of these top-down control effects are likely to vary in response to seasonal hydrology. The top aquatic predators within the site (for example, barramundi, saltwater and freshwater crocodiles) similarly have a strong influence on lower components of food chains.

5. *Omnivory is widespread and food chains are short*. Widespread omnivory is a characteristic of tropical fish communities, thought to be a response to the strong seasonal variability in the availability of food resources. This omnivory means that fish feed on a broad range of items, often across several trophic levels, which results in short, diffuse and highly interconnected food webs.

3.7 Critical Services/Benefits

The present study identifies three critical services/benefits for the Kakadu National Park Ramsar site (Table 3-1). In the context of the nomenclature outlined by the Millennium Ecosystem Assessment (2003), critical services/benefits for the site are classified as follows:

- S1 – Maintenance of Global Biodiversity, which is considered to represent a supporting service.
- S2 – Fisheries Resource Values, which can be considered to represent cultural, supporting or provisioning services.
- S3 – Contemporary Living Culture, which can be considered to represent a cultural service.

3.7.1 S1 – Maintenance of Global Biodiversity

Reasons for Selection as 'Critical'

Biological diversity, or biodiversity, is the variety of all life forms, the genes they contain and the ecosystem processes of which they form a part. The term biodiversity can therefore incorporate most of the critical and supporting components outlined in the previous sections. However, in the context of how the Ramsar site provides a critical role in maintaining global biodiversity, two critical components together have been selected in the context of this critical service:

- supporting critical habitat for globally and nationally threatened wetland-dependent species, and
- supporting critical habitat for locally endemic species.

These two critical components are also important in their own right. The role of the site in maintaining threatened wetland fauna species underpins Ramsar Nomination Criterion 2, and was identified by Fox *et al.* (1977) as justification for National Park declaration (refer Fox *et al*. 1977). Endemic species form a key element of biodiversity, as recognised in Section 70 of Ramsar Convention Secretariat (2007), which underpins Ramsar Nomination Criterion 3.

In addition to the values of these species in terms of maintaining global biodiversity, some species are of great scientific research value (see Section 3.7.1), provide a cultural resource (for example, pig-nosed turtle, see Section 3.7.3) and/or play a role in maintaining wetland ecosystems and foodwebs (see general account in Section 3.5.5).

Description

Five globally or nationally threatened species are considered to have critical habitat within the Ramsar site (Table 3-8). Several other threatened species are also known or likely to occur in the site, however the site is not considered to represent critical habitats for these species (see Section 2.5.2). The role of the wetlands within the Ramsar site in maintaining these species, together with patterns in variability, are described in other sections relating to critical components and processes (see Table 3-8).

Refer to Section 3.2.11 (Critical Component C11) for an account of locally endemic invertebrate species within the Ramsar site.

Table 3-8 Threatened wetland species that have critical habitats within the Ramsar site

Species	Reproduction	Recruitment	Feeding	Population	Critical Element
Northern river shark	Unknown.	Yes – neonates and juveniles appear to be restricted to estuaries.	Yes – turbid rivers.	Small, highly fragmented population globally (New Guinea and Australia). South, East and West Alligator Rivers, and three other localities external to the Ramsar site, support this species (Compagno *et al*. 2008).	C8
Speartooth shark	Unknown but possible.	Yes – neonates and juveniles restricted to upper estuary.	Yes – turbid rivers.	Small, highly fragmented population globally (New Guinea and Australia). East and South Alligator Rivers are two of the five known Australian localities supporting this species (Compagno *et al.* 2008).	C8
Pig-nosed turtle	Yes – nest on river banks.	Yes.	Yes – particularly billabongs	Breeding populations in Australia are known in the East and South Alligator Rivers, with two other known localities external to the site and a number of other anecdotal reports (Doody *et al.* 2000). Also occurs as isolated population in New Guinea (Cogger & Heathcote 1981).	C10
Flatback turtle	Yes – critical nesting site.	No.	No.	Field Island represents one of six major nesting sites in Australia, and has been identified as a habitat critical to the survival of this species.	P4
Yellow chat	Yes.	Yes.	Yes.	Small geographic area encompassing the floodplains from the Adelaide River to the East Alligator River, (Woinarski *et al.* 2007). Total population size estimated to be about 500 breeding birds (Garnett and Crowley 2000) and Kakadu National Park sub-population probably around 300 (Armstrong 2004).	C9
Freshwater and dwarf sawfish	Possibly - Freshwaters of large river systems.	Possibly - Freshwater and upper estuaries.	Yes.	Both have a wide geographic distribution but highly fragmented, and thought to be uncommon where they occur. Freshwater sawfish recorded in eight catchments within Northern Territory, including South and East Alligator Rivers (Peverell *et al.* 2006). Population size unknown. Dwarf sawfish recorded in five catchments, including South Alligator River (Peverell *et al.* 2004)	N/A
Green turtle and dugong	No.	No.	Some feeding – but not core area.	Limited area of feeding habitat (intertidal seagrass) within the site is not critical to maintaining populations of these species at even a local scale.	N/A

Blue shading – site is not known to be a critical habitat for this species

3.7.2 S2 – Fisheries Resource Values

Reasons for Selection as 'Critical'

Kakadu National Park supports important fisheries resources in the form of fisheries habitats. This was selected as a critical service/benefit due to fisheries values being an important determinant of the site's unique character, and the importance of fisheries values with respect to support of other services/benefits including recreation and tourism (supporting service) and contemporary living culture (Service 3). This service/benefit is based on fisheries habitat and fish abundance, and excludes fishing activities.

In the context of this service, barramundi *Lates calcarifer* has been selected as a key indicator of the fisheries habitat values of the site. Selection of barramundi as a key indicator is based on a number of reasons: recreational fishing focuses almost entirely on this species, has been relatively well-studied and also represents a key traditional food species together with other cultural values (refer Section 3.7.3). Habitat values and patterns in the abundance of barramundi are discussed below.

3.7.2.1 Habitats

Description

All wetland types together support the ecosystems and constituent habitats, populations and food webs that support fisheries resource values within and adjacent to the site. Commercial fishing is banned throughout the site and no recreational fishing is allowed upstream of the Kakadu Highway, except on Jim Jim, Muirella Park and Sandy Billabongs, and Yellow Water. Fishing is also prohibited on the West Alligator River and some other billabongs. Due to the wide home range of many estuarine and marine species, the site is also likely to support habitats and other fisheries resources that contribute to fisheries productivity outside the site.

Most commercially important species, including barramundi, use a wide range of habitats (and habitat patches) as part of their life-cycle. It is therefore appropriate to consider fisheries habitat values in the context of:

- the range habitat types supporting different life-history functions of different fisheries species (and their prey, for example, bony bream, mullet, rainbowfish etc.)
- hydraulic (flow regimes) and bio-physical habitat conditions, which ultimately control patterns in fish community structure across a range of spatial and temporal scales
- connectivity/linkages between different habitat types and patches, which vary seasonally
- specific environmental conditions and stresses within particular habitat patches (for example, water quality conditions), and
- biological interactions (particularly predation, prey availability) within particular habitat types and patches.

Patterns in Variability

In the context of describing natural variability in fisheries resource values, the following habitat characteristics have been selected as indicators:

- area of floodplain, billabongs, mangrove, saltmarsh, intertidal flat habitats (bio-physical habitat indicators)
- estuary length, perimeter and area, and
- annual flow volumes (broad hydraulic habitat indicator).

Section 3.3 describes patterns in natural variability in the extent/distribution (where known) of seagrass, mangroves, intertidal flats, monsoon rainforest supported by springs, permanent waterholes and seeps in stone country, *Melaleuca* forest, and palustrine wetlands and billabongs.

The additional habitat indicators considered in the context of this service are floodplain area and estuary length, perimeter and area (refer Table 3-9). Note that the estuary indicators are for the maximum, dry season extent of the estuary. Flooding (during the wet season) often results in the estuary retracting to near the river mouth within the South Alligator River (Vertessy 1990), and most likely in the other catchments. However, following flood recession, salt propagates upstream such that by the end of the dry season, sea water salinities are attained near the tidal limit of the South Alligator River (Vertessy 1990).

Table 3-9 Key catchment, estuary and flow descriptors for each catchment within Kakadu National Park

Parameter	Catchment			
	East Alligator	South Alligator	West Alligator	Wildman
Catchment area (km^2)[B]	15 871	11 921	2228	2476
Maximum estuary length (km)[B]	64.3	78.52 (103 km)	28.02	32.31
Maximum estuary perimeter (km)[B]	164.3	172.7	58.82	66.2
Maximum estuary area (km^2)[B]	92.47	105.2	9.43	4.37
Mean annual rainfall (mm/yr)[B]	1379	1363	1396	
Mean annual flow (ML/yr)[B]	6 870 000*	5 750 000**	815 000***	
Mean annual runoff (mm/yr)[B]	601	555	566	

B = NLWRA (2001), taken to mean the upstream extent of saltwater influence (dry season)

Mean annual flow from: * Gauge Stations G821010 and G821009; ** Gauge station G820112; *** Gauge station G819001.

With the exception of a study by Hess and Melack (2003) which had limited spatial and temporal context, there are few empirical data describing patterns in variability in estuary size and floodplain inundation area within the site. However, in qualitative terms, it is known that floodplains of the site are a hydrologically dynamic habitat. During the annual wet season, the underlying clay soils are flooded by 10 to 200 centimetres of water, while during the dry season they are dry and deeply cracked. The annual wetting and drying cycle is a reliable occurrence, but the timing of wet season onset, and the extent and duration of inundation are not (see Section 3.5.1). Maintenance of the seasonal flooding regime is critical to the maintenance of aquatic foodwebs and wetland ecosystem functioning (Douglas *et al.* 2005; see Section 3.5.5). River flow dynamics, and patterns in variability, are described in Section 3.5.1 of this report.

3.7.2.2 Barramundi Abundance

Description

Recreational fishing within the site is based almost entirely on barramundi. The maximum allowable catch is two fish per day per person (Director of National Parks 2007). Under the Northern Territory *Fisheries Act 2005*, Indigenous people may fish by traditional methods in traditional areas, and are otherwise subject to the same controls as recreational fishers. The catch by Indigenous people in the Northern Territory was estimated to be 44 134 barramundi in 2000 (Coleman *et al.* 2003), however the contribution of the site to this total catch has not been quantified.

There are insufficient recent data to determine key fishing areas and fish production within the site. However, creek surveys undertaken in 1986-1987 between Darwin and East Alligator River indicated that South Alligator River and East Alligator River ranked second and third respectively to Mary River in terms of recreational fishing effort (approximately 29 percent and 10 percent of total effort, respectively) and catch (approximately 9000 fish in South Alligator River in 1986) (Griffin 1989). Notably, compared to a survey done in 1978-1979 using the same methods, recreational effort had increased by approximately 27 percent and catch by approximately five percent (Griffin 1989). However, it is likely that recreational fishing effort has increased markedly since the 1986-1987 survey due to the increase in visitor numbers to the Park (refer Section 3.8.1).

In the context of this critical service, Kakadu National Park is an important breeding, recruitment and feeding site, as well as dry season refugia. Barramundi ecology is strongly influenced by fluvial hydrology and tidal processes (Pusey *et al*. 2004). In addition to its role in controlling geomorphology and therefore habitat structure, freshwater flows and tidal processes ultimately control spawning, feeding and abundance patterns during all life-cycle stages (Pusey *et al*. 2004). The catchments of the site have a large river discharge and low catchment gradient (and associated high residence time of fluvial flows), which together with the relatively undisturbed condition of floodplain habitats, provide the necessary conditions for maintaining high barramundi abundances (Pusey *et al*. 2004).

Spawning occurs in estuarine creek mouths, with spawning sites typically in areas with low tidal current velocities (Pusey *et al*. 2004). The on-set of spawning is thought to occur immediately prior to the wet season, and is thought to be linked to water temperature (Pusey *et al*. 2004). Barramundi are tolerant of a wide range of water quality conditions (i.e. salinity, dissolved oxygen, turbidity). However local fish kills can occur in drying water holes in response to high water temperatures and low dissolved oxygen concentrations (Pusey *et al*. 2004), as well as after rainfall when deoxygenated, nutrient enriched waters flow into waterholes. Barramundi is not known to have a highly selective diet, but does vary according to age (small invertebrates and small fish as juveniles, fish, prawns, crabs as adults) (Pusey *et al*. 2004). Prey items can be strongly influenced by flows and water quality conditions.

Patterns in Variability

The key indicator in the context of this critical service is barramundi abundance. Barramundi abundance has been assessed at Yellow Water billabong in September 1990 by Griffin (1994). Griffin (1994) suggested that the population was comprised of approximately 6000 individuals at that time, with catch per unit effort (CPUE) of 3.8 fish per 100 metre net per hour. At Corroboree Billabong on the Mary River, the CPUE was 6.7 fish per 100 metre net per hour.

Long-term fish monitoring studies by *eriss* provide standardised, empirical fish catch data from two sandy bed billabongs located in Nourlangie Creek (Sandy Billabong) and Magela Creek (Mudginberri Billabong) sub catchments (based on visual census techniques – see Humphrey *et al.* 2005). Over the monitoring period 1994 to 2005, the mean overall number of barramundi recorded per 50 metre (using the visual boat census technique) was 0.987 individuals per 50 metres at Mudginberri Billabong, and 0.283 individuals per 50 metres at Sandy Billabong (see Section 3.2.6).

There are no available data describing patterns in barramundi abundance over time or within other areas of the Ramsar site.

3.7.3 S3 – Contemporary Living Culture

Reasons for Selection as 'Critical'

Contemporary living culture was selected as a critical service as it is an important determinant of the site's unique character. In particular, it is noteworthy that the Kakadu National Park Ramsar site meets all four of the Ramsar cultural characteristics as outlined by Resolutions VIII.19 and IX.21 (cultural characteristics 'a', 'c' and 'd' described below; refer Section 3.8.3 for cultural characteristic 'b').

Description

Bininj within Kakadu National Park undertake cultural and land management practices, follow customary law and uphold traditions established over thousands of years of continuous occupation. Kakadu National Park's contemporary 'living culture' is described under three of the Ramsar cultural characteristics below.

Maintenance of the living culture is dependent on factors such as land ownership, access to land and resources, transmission of cultural knowledge and practices to younger generations, protection of sites and documentation of cultural heritage.

Cultural characteristic 'a': Sites which provide a model of wetland wise use, demonstrating the application of traditional knowledge and methods of management and use that maintain the ecological character of the wetland.

The management of Kakadu National Park provides a model of wetland wise use, incorporating traditional knowledge and providing a balance between competing interests such as nature conservation and tourism. Kakadu National Park's model of joint-management between Bininj and the Australian Government is renowned on a worldwide scale for its success in its integration of Bininj and western management techniques, as well as its recognition of Indigenous land rights and self-determination (de Lacy 1994).

Sustainable Use

Bininj and Parks Australia have developed a successful system of wise-use whereby Bininj can sustainably harvest native plants and animals within the national park. This system is critical in maintaining Bininj cultural heritage as Traditional Ecological Knowledge is transferred (for example, harvesting techniques, species' ecology), Bininj languages are used, other cultural practices are undertaken while harvesting traditional foods, and land management is often undertaken simultaneously. Resources that are harvested may be used for food, art and craft, medicine and other customary uses, as described in further detail below. Bininj continue to hold detailed knowledge of the usage, availability and ecology of hundreds of plant and animal species (Brockwell *et al* 1995).

Threat Management

Bininj knowledge has assisted Parks Australia in monitoring and managing threats to the Ramsar site, thereby maintaining the ecological character. For example, feral buffalo were causing extensive environmental damage during the 1960s through vegetation destruction, soil compaction, weed dispersal, habitat modification and erosion (see Higgins 1999, Director of National Parks 2007). Bininj and local community members established a buffalo control program to reduce buffalo numbers, and started to restore wetlands in the 1970s. Bininj traditional ecological knowledge regarding the original state of the environment, the impact of buffalo and the management and restoration of wetlands was central to the successful restoration of the wetlands (D. Lindner pers. comm. 2009).

Cultural characteristic 'c': Sites where the ecological character of the wetland depends on the interaction with local communities or Indigenous peoples.

Through historical and current practices, Bininj have influenced, and continue to influence, the ecological character of the Kakadu National Park Ramsar site. Bininj hold a substantial body of traditional ecological knowledge which includes topics such as fire, species, ecosystems, ecological processes, landscape change and seasons. A joint management arrangement enables Bininj to look after Kakadu National Park in cooperation with National Park staff, providing opportunities for relevant Bininj to be consulted, make decisions and implement these in the management of Kakadu National Park. As such, the application of traditional ecological knowledge and cultural knowledge in land management, cultural heritage management and tourism contributes towards maintaining the ecological character of the wetlands and surrounds.

Bininj and the local community have been working with Parks Australia North on natural resource management programs since the inception of Kakadu National Park. Approximately 30 percent of the staff employed through Kakadu National Park are Bininj people with 20 percent having a close connection to Kakadu National Park or the region (S. Winderlich pers. comm. 2009). Bininj and the local community have also initiated a number of programs over the years to deal with threats to Kakadu National Park's ecological character, notably *Mimosa pigra* control, restoration of billabongs at Gina and Yellow Water, fencing for protection of cultural sites and the re-establishment of floodplain burning (information provided through Kakadu National Park ECD Workshop Jabiru 2009).

Fire Management

Fire management is a particularly important interaction that influences the ecological character of the Ramsar site. Archaeological records reveal an increase in charcoal and a change in vegetation after the arrival of Bininj, suggesting that fire was being actively managed by humans and was consequently having a significant impact on the environment (Hiscock and Kershaw 1992). Fire was an important tool for expressing ownership, for managing food resources, as a hunting strategy, for clearing grasses and undergrowth to make travel easier, for communication, for defence and for specific spiritual and cultural obligations (Russell-Smith 1995, Director of National Parks 2007). For example, wetland burning has transformed Boggy Plain from a dense monoculture of grass to a mosaic of diverse habitats rich in resources. The Boggy Plain project has assisted in passing on Traditional Ecological Knowledge to younger generations.

The present vegetation communities and suites of fauna are dependent on the traditional burning practices established by Bininj over a long period of time (Director of National Parks 2007, Russell-Smith 1995). Bininj work with Parks Australia to develop fire management strategies and annual burning plans that replicate traditional burning (Director of National Parks 2007, also see Section 3.5.2).

Cultural characteristic 'd': Sites where relevant non-material values such as sacred sites are present and their existence is strongly linked with the maintenance of the ecological character of the wetland.

'In some cultures, belief systems do not differentiate between the economic, social, cultural and spiritual value of wetlands and people seem to have a more holistic perspective of their world. Indigenous people in Australia consider themselves an integral part of their natural environment. With the poorest soils of any inhabited continent and with a very dry climate, the high productivity of Australia's wetlands has given them special significance for these people. Their wetlands are very often sacred to them: they are story places and evidence of the work of the ancestral creators who made the landscape and provided for the needs of people. This holistic perspective is also found in many indigenous belief systems in Africa and the Americas.

The spiritual connection between people and wetlands has a long history and is still of great significance today in many cultures, their belief systems and traditions representing an important feature of wetland cultural heritage – and at the same time often ensuring the conservation and wise use of wetlands.' (Ramsar Convention Secretariat 2002).

The Kakadu National Park landscape is overlain by a complex spiritual and social system sustained by Bininj. Bininj believe that the natural features in the current landscape reflect the journey and actions of the first people, the Nayuhyunggi. The living essence of some of these first people remains in the land, and as such all land is valuable under this spiritual perspective, with some sites viewed as particularly sacred or significant (Chaloupka 1993). Further information regarding culturally significant sites is provided in Section 3.8.5 below.

Sites of cultural significance are important to the maintenance of the ecological character of Kakadu National Park, as many of these sites must remain undisturbed in order not to disrupt the powers of the creation ancestors residing within. Many sites need to be cared for and some even require the practice of increase ceremonies to ensure that the plants, animals and people of Kakadu National Park prosper.

3.8 Supporting Services / Benefits

The supporting services/benefits outlined below are considered to be important or noteworthy in the context of maintaining the character of the site, but are not considered to represent critical services/benefits in the context of the considerations outlined in section 3.1.1 of this report. In this context:

- The supporting services/benefits are not, in isolation, thought to fundamentally underpin the listing criteria. However, supporting services/benefits may, in combination with other elements, underpin nomination criteria.
- Some supporting services/benefits are already partially covered by other critical components, processes or services/benefits.
- The supporting components, while not critical, are important to wetland functioning and are noteworthy in this regard.

In addition to these services, it is recognised that the Katherine River provides a source of water for the township of Katherine (Simon Ward, pers. comm. 2010). The specific values of the site in maintaining these flow regimes and water resource values for Katherine have not been quantified, and this represents an information gap in the context of this ECD.

3.8.1 Recreation and Tourism

Kakadu National Park is an iconic destination for both international and Australian visitors. Tourists are attracted to Kakadu National Park for its wildlife and magnificent landscapes, as well as for its ancient cultural heritage including impressive galleries of Aboriginal rock art (Commonwealth of Australia 1988, Director of National Parks 2007). Furthermore, the World Heritage listing of Kakadu National Park is also likely to contribute to the attractiveness of the Ramsar site as a tourist destination (Director of National Parks 2007). International visitors are principally from the United Kingdom, Germany and the United States (Figure 3-23).

Tourist access is controlled through the Kakadu National Park Management Plan 2007-2014 (Director of National Parks 2007). Specifically, the Management Plan aims to maintain '*a strong and successful partnership between traditional owners, governments, the tourism industry and Park user groups, providing world's best practice in caring for country and sustainable tourism'.* Evaluation of achievement of the aim is measured through the (Director of National Parks 2007):

- level of Bininj satisfaction with the nature, scope and impact of recreational and tourism opportunities in the Park
- level of visitor and tourism industry satisfaction with recreational and tourism opportunities in the Park, and
- the extent to which Bininj gain economic benefit from commercial tourism opportunities.

Major tourism infrastructure is provided at locations such as Gagudju Lodge Cooinda and Aurora Kakadu Resort, including accommodation, restaurants, pubs and service infrastructure. Camping sites, caravan sites, boat ramps, lookout points, walkways and information bays are also provided at a number of locations throughout the Park. Other notable features include the Bowali Visitor Centre that features displays, audio-visual presentations and information staff, the Marrawuddie Gallery of Aboriginal fine arts (located at the Bowali Visitor Centre), and the Warradjan Aboriginal Cultural Centre that displays detailed information about local Aboriginal culture.

A variety of tourism enterprises exist, including commercial boat cruises, recreational fishing tours, cultural interpretive tours, bird-watching tours, four wheel drive and waterfall tours and multi-day tours throughout the park. Substantial numbers of tourists support these enterprises. For example, it has been estimated that 100 000 people take commercial boat cruises per year (R. Murray pers. comm. cited in BMT WBM 2010). However, it is also noted that many tourists travel independently of these tours.

Closely linked to tourism, the Ramsar site provides opportunities for a range of recreational activities. In particular, people from Darwin, Katherine and Pine Creek regularly use the Park for recreation. Recreational activities within the Ramsar site have a predominant conservation focus, including bushwalking, swimming, boating and fishing. Highlighting the significance of recreational activities within the Ramsar site, 20 percent of the Northern Territory's recreational barramundi fishing occurs within Kakadu National Park (Tremblay and Boustead 2009).

The tourism industry is the main source of employment in the Kakadu National Park region, followed by recreation and conservation (Bayliss *et al.* 1997). As such, tourism and recreation are very important for the regional economy as well as that of the Northern Territory. Kakadu National Park contributes significantly to the Northern Territory economy (M. Triggs pers. comm. cited in BMT WBM 2010). Furthermore, the economic significance of the park is evidenced through purchase of significant quantities of goods and services from regional suppliers (Director of National Parks 2007).

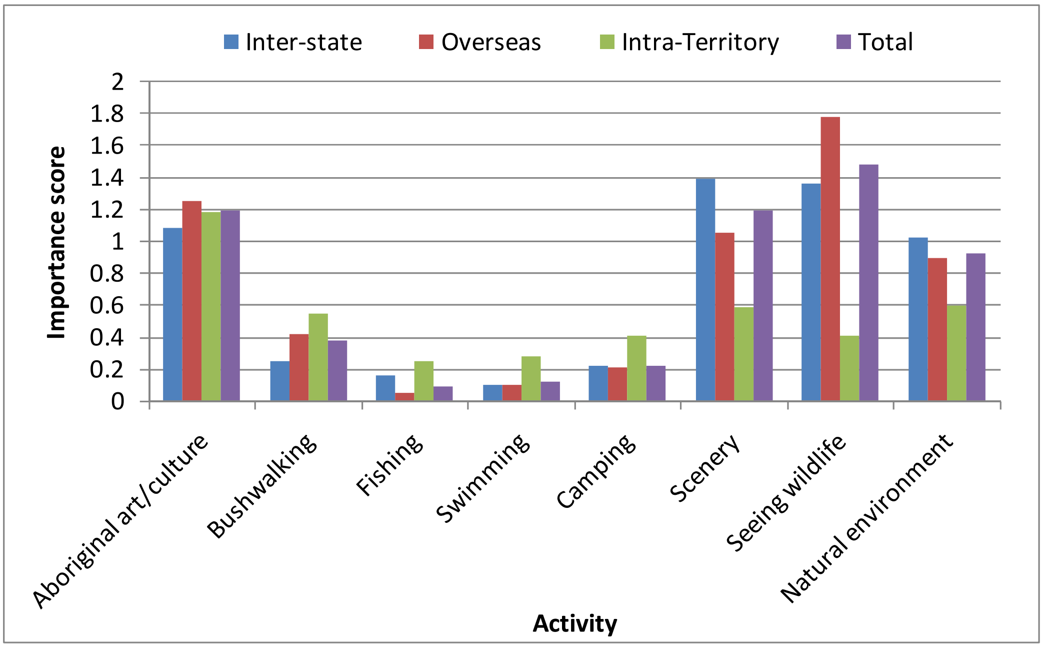

Figure 3-22 Main reasons for visiting Kakadu National Park (source: Tremblay 2007)

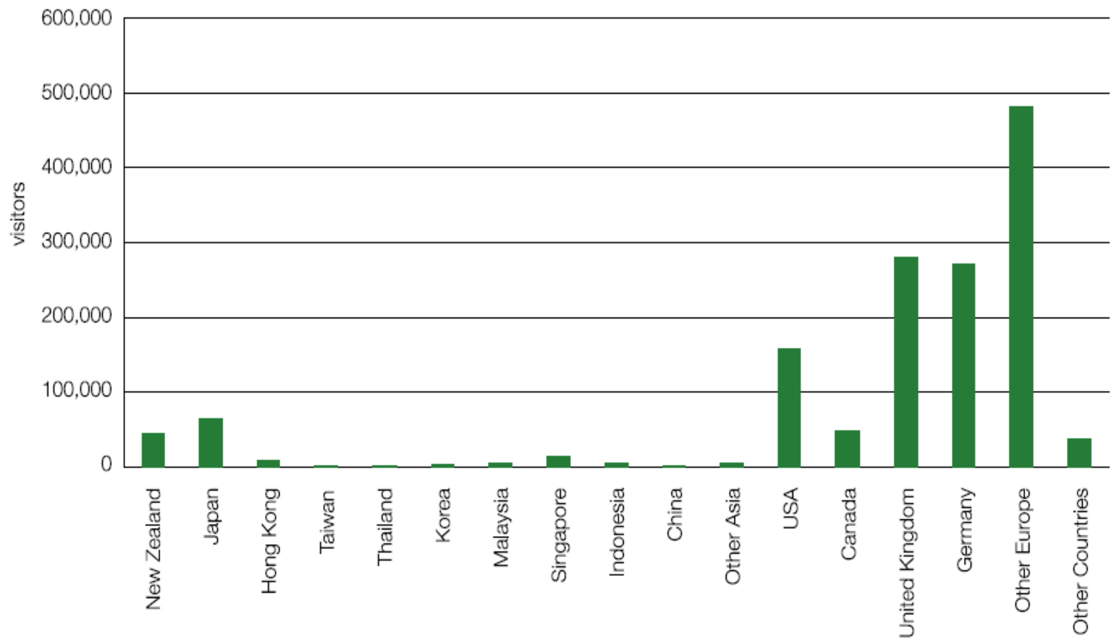

Figure 3-23 Total international visitors numbers for Kakadu National Park (1998-2003 combined) (source: Morse *et al.* 2005)

Tourist visitor numbers to Kakadu National Park have increased significantly since the Park was declared, increasing from 45 800 visitors in 1982 (Commonwealth of Australia 1988) to an average of 230 000 visitors in the 1990s (Kakadu National Park Board of Management and ANCA 1996 cited in Bayliss *et al.* 1997). The trend in increasing tourist numbers during the 1980s (around the time of site listing) is shown in Figure 3-24 below. However, visitor numbers have displayed gradual declines over the past 15 years (Morse *et al.* 2005). In terms of recent data, it is known that 228 899 people visited Kakadu National Park in 2008 (S. Murray pers. comm. cited in BMT WBM 2010).

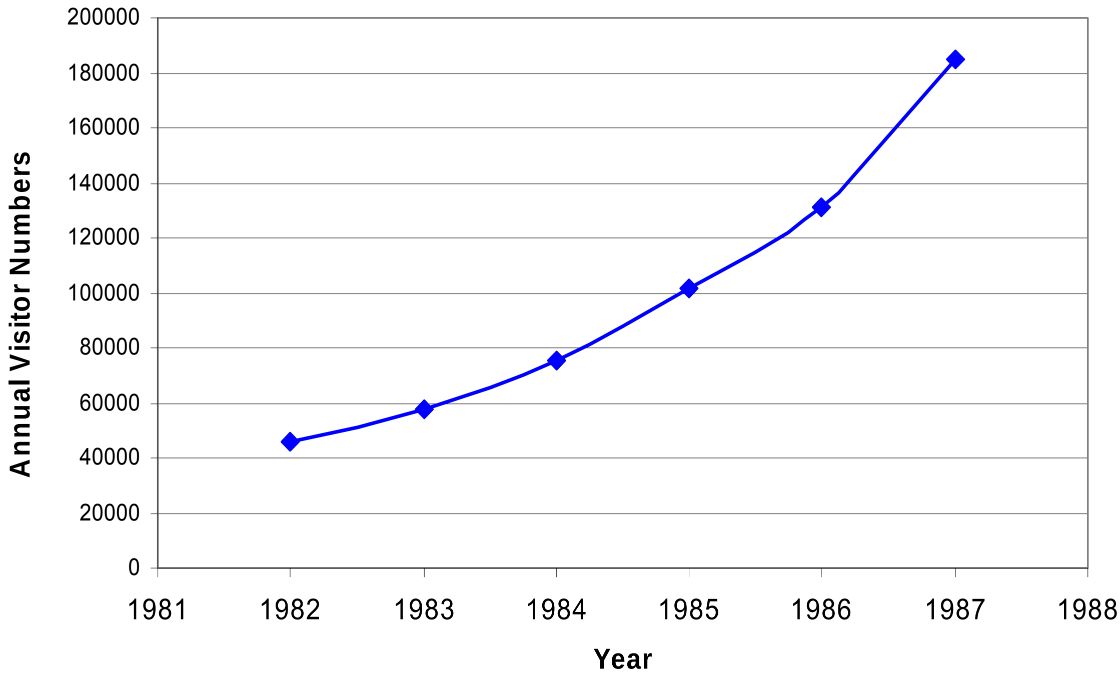

Figure 3-24 Annual visitor numbers to Kakadu National Park in the 1980s (source: Commonwealth of Australia 1988)

3.8.2 Scientific Research and Education

As demonstrated by this ECD, Kakadu National Park provides a wide range of habitats that present opportunities for scientific research activities. In particular, the near-natural nature of wetlands within the Ramsar site makes it an ideal ‘reference’ or ‘benchmark’ location for scientific research. Of further relevance with respect to scientific importance, several specimen type localities for species are located within the Ramsar site (for example, for endemic fauna and flora, refer Section 2.5.3).

A great diversity of scientific research has been undertaken within the Ramsar site. Research activities, like other activities in the Park, are regulated under the EPBC Act and the Kakadu National Park Management Plan. The following organisations are particularly noteworthy in terms of their contribution to scientific research within Kakadu National Park:

- *eriss* undertakes a range of scientific monitoring and research activities into the environmental impact of uranium mining in the Alligators Rivers Region of Kakadu National Park. The *eriss* head office and research laboratory facility is located in Darwin, and a field station is located at Jabiru. Examples of ecological research undertaken by *eriss* include studies on fish (for example, Bishop *et al.* 1981, 1986, and 1990), flora (for example, Cowie and Finlayson 1986, Cowie *et al.* 1988, Finlayson *et al.* 1989, 1992 and 1994, Brennan 1996), frogs (for example, Tyler and Cappo 1983, Tyler and Crook 1987) and birds (for example, Dostine and Skeat 1993, Morton *et al.* 1991).

- Several universities have had a long-standing interest in the site, especially Charles Darwin University (CDU). For example, CDU post-graduate students have researched sea turtles (Vanderlely 1995), magpie geese *Anseranas semipalmata* (Whitehead 1998), mammals (Watson 2008) and *Melaleuca* distribution (Staben 2008), as well as a range of geomorphological studies.
- The Cooperative Research Centre for Tropical Savannas Management (Tropical Savannas CRC) was established and supported by the Australian Government. Researchers that are part of the Tropical Savannas CRC have conducted research that has focussed on land-management issues such as fire and weeds within Kakadu National Park (for example, Edwards *et al.* 2003, Price *et al.* 2005).
- Tropical Rivers and Coastal Knowledge (TRaCK) is a research consortium led by CDU, CSIRO, Griffith University, Land and Water Australia, the North Australia Indigenous Land and Sea Management Alliance and the University of Western Australia. TRaCK coordinates social, economic and environmental research in order to sustainably manage the opportunities and expectations for rivers and water resources of northern Australia.
- Various Northern Territory Government departments have conducted scientific research within the Ramsar site. For example, Parks and Wildlife Service (within NRETAS) have conducted research on marine turtle nesting (for example, Chatto and Baker 2008).

A number of knowledge gaps that require further scientific research have been identified for each of the critical components, processes and services/benefits (refer Section 7.1). As such, the Ramsar site is seen as a critically important for expanding scientific knowledge. Furthermore, baseline monitoring studies are an important component of future scientific research in order to ensure that the values of the Ramsar site does not become degraded over time.

In terms of environmental education, the Park is regarded as having outstanding education and interpretive displays and information material that is showcased at the Bowali Visitor Centre and at various attractions throughout the Park. The Ramsar status of the site is specifically highlighted in signage at the Mamukala wetlands located in the South Alligator River floodplain (refer Figure 3-25).

Figure 3-25 Ramsar signage at Mamukala wetlands (source: BMT WBM)

3.8.3 Historical Cultural Heritage

Kakadu National Park is home to the world’s oldest living culture. With respect to the historical cultural heritage of the Ramsar site, Kakadu National Park has exceptional cultural traditions as well as records of former civilizations that have influenced the ecological character of the wetlands. Thermoluminescence dating suggests that Bininj have occupied Kakadu National Park for between 50 000 and 60 000 years (Jones and Negerevich 1985, Chaloupka 1993, Brockwell *et al.* 1995).

The Kakadu National Park landscape contains exceptional records of Bininj occupation. Through their activities, Bininj have left a large assemblage of archaeological material including occupation sites, rock art, shell mounds and middens, stone tools and burial sites. Excavation of such material has provided detailed insight into the hunter-gatherer lifestyle over many thousands of years (Brockwell *et al.* 1995). These archaeological records are widely distributed within the Ramsar site, found in open sites on the flood plain, wetlands and coastal plains, in rock shelters and open sites throughout the valleys and outliers of the Arnhem Land plateau and in rock shelters in the sandstone country on the escarpment plateau (Brockwell *et al.* 1995). The South Alligator River floodplain alone contains an archaeological assemblage of possibly 25 000 000 artefacts (Meehan *et al.* 1985).

A number of Bininj languages are used in Kakadu National Park, including Gundjeihmi, Kunwinjku and Jawoyn. These languages are maintained through their everyday use in Bininj communities, through documentation and through using the Bininj language name for places in the park, bush tucker and in interpretive material (Director of National Parks 2007). The maintenance of language is recognised as an important component of protecting the cultural heritage and reservoir of traditional ecological knowledge for Kakadu National Park.

3.8.4 Biological Products

As described in Critical Service 3 above, Aboriginal communities have a strong relationship with ecosystems of the Ramsar site. In particular, ecosystems are important with respect to provision of biological products including traditional foods (termed 'bush tucker') as well as materials that are useful for various purposes. While the diet and customs of Aboriginal communities may have changed since European colonisation, many traditional biological products are still sourced from ecosystems.

Bush Tucker

Species that are known to be included in the traditional diet are listed in Table 3-10 below. As indicated in the table, a large proportion of the bush tucker species originate from floodplains and billabongs. Of particular note are magpie geese *Anseranas semipalmata* and their eggs, which are regarded as one of the most important animal staples in the traditional diet (Lucas and Russell-Smith 1993). Other major sources of animal protein include freshwater mussels, fish, turtles, and crocodile eggs. The most abundant sources of carbohydrate include several species of water lily *Nymphaea* spp. and water chestnut *Eleocharis dulcis*, with a variety of other plant species used as minor sources of carbohydrates (Cowie *et al.* 2000).

Materials

Biological products have a variety of customary uses such as medicine, craft, weapons and utensils. The following examples of resources that are derived from biological products are provided in Cowie *et al.* (2000):

- common swamp reed *Phragmites vallatoria* is used for fighting spears or goose spears
- a bamboo *Bambusia arnhemica* is used for spears, craft and didgeridoos
- common bulrush *Typha domingensis* is used for spears
- bark from the shrub *Melochia corchorifolia* is used for fibre for making string
- bark from paperbarks *Melaleuca* spp. is used for carrying or wrapping food, for shelter, for torches and as traditional medicine, and
- bark from freshwater mangrove *Barringtonia acutangula* is used for poisoning fish.

Other notable examples of materials include swamp banksia *Banksia dentata* that is used as fire sticks, and spring pandanus *Pandanus spiralis* that is used to make dilly bags, mats and baskets (Wightman and Brown 1994).

Table 3-10 Native animal and plant species in the Aboriginal diet (source: Lucas and Russell-Smith 1993)

Bininj (Gundjeyhmi) Name	Scientific Name	Common Name	Habitat
Fruit and Seeds			
Maardjakalang	*Nymphaea macrosperma*	water lily	Floodplain
Yalgei	*Nymphaea pubescens*	water lily	Floodplain
Andem	*Nymphaea violacea*	water lily	Floodplain
Yams			
Gaamain	*Amorphophallus paeonifolius*	elephant yam	Lowland jungle
Anbidjoh/Angodjbang	*Aponogeton elongatus*	aquatic tuber	Creeks/springs
Angindjek	*Dioscorea bulbifer*	round yam	Jungle
Angaiyawol/Gorrbada	*Diocorea transversa*	long yam	Jungle
Angulaidj	*Eleocharis dulcis*	water chestnut	Floodplain
Galaarum	*Eleocharis* spp.	spike rush	Floodplain
Anburrei	*Ipomea* spp.	yam	Sandstone
Wurrumaning	*Nelumbo nucifera*	lotus lily / red lily	Floodplain
Maardjakalang	*Nymphaea macrosperma*	water lily	Floodplain
Yalgei	*Nymphaea pubescens*	water lily	Floodplain
Andem	*Nymphaea violacea*	water lily	Floodplain
Anbuled/Buldeer/gukbam	*Triglochin procerum*	water ribbons	Floodplain
Fish			
Anmakawarri	*Arius leptaspis*	salmon catfish	Billabong
Dunbukmang	*Hephaestus fuliginosus*	black bream	Billabong
Gulobirr	*Sclerpages jardini*	saratoga	Billabong
Namanggorl	*Lates calcarifer*	barramundi	Billabong
Reptiles			
Ginga	*Crocodylus porosus*	saltwater crocodile (eggs)	Billabong/river
Gumugen	*Crocodylus johnstoni*	freshwater crocodile (eggs)	Billabong
Birrnining	*Varanus indicus*	mangrove monitor	Floodplain/mangroves
Djanai/Dalag	*Varanus panoptes*	sand monitor	Floodplain
Galawan	*Varanus gouldii*	Gould's goanna	Woodland
Bolorgoh	*Lialis fuscus*	water python	Floodplain
Nauwandak	*Acrochordus arafurae*	arafura file snake	Billabong
Almangiyi	*Chelodina rugosa*	long-necked turtle	Floodplain
Ngardehwoh	*Elseya dentata*	short-necked turtle	Billabong
Warradjang	*Carettochelys insculpta*	pig-nosed turtle	Billabong
Birds			
Bamurru	*Anseranas semipalmata*	magpie goose (meat and eggs)	Floodplain
Marsupials			
Gornobolo	*Macropus agilis*	agile wallaby (male)	Woodland
Merlbe	*Macropus agilis*	agile wallaby (female)	Woodland
Mammals			
Nangamor	*Pteropus scapulatus*	little red flying-fox	Creeks, springs, jungle
Nagaiyalak	*Pteropus alecto*	black flying-fox	Creeks, springs, jungle

Note: 'Bininj (Gundjeyhmi) name' means Aboriginal name in the local Gundjeihmi language

3.8.5 Sites and Items of Cultural Significance

There are several items and sites of cultural significance that are important in terms of gaining an understanding of the historical cultural heritage, as well as sites and items that continue to have significance in terms of the contemporary living culture of the Kakadu National Park Ramsar site. These are detailed as follows:

Traditional Camping Areas

Traditional camping areas, or occupation sites, are found throughout Kakadu National Park from the coast, along the rivers, to the floodplain and into the outliers and main escarpment area. These camping areas can be a focal point for artefacts and middens, as well as rock art.

Rock Art

It is estimated that there are at least 10 000 art sites throughout Kakadu National Park, primarily located in the escarpment and its outliers (Brockwell *et al.* 1995). The rock art tells a story of landscape change over thousands of years (Chaloupka 1993), and enhances other archaeological research by providing details of economic activities, technology and material culture, as well as insights into ideology, religion and traditional life (Brockwell *et al* 1995). The rock art of Kakadu National Park is internationally significant due to its extensiveness, antiquity, exquisite beauty and artistic excellence, and as it is the world's longest continuing art tradition (Chaloupka 1993, Brockwell *et al.* 1995).

Shell Mounds and Middens

Shell mounds and middens are found on the floodplains, rivers and coastal regions. Specific sites include Ngarradj Warde Djobkeng, Malakunanja, Nawamoyn, Paribari and Malangangerr. These sites are dated as far back as 7000 years before present, during Kakadu National Park's 'big swamp' period when the mangrove landscape provided abundant molluscs for exploitation (Hiscock 1999). Comparison of midden variability in faunal composition, location of middens, time period and intensity of use, and associated artefacts (for example, stone tools) have contributed greatly to the understanding of the archaeological record of Australia.

Stone and Organic Tools

Early stone tools found in Kakadu National Park rock shelters from at least 20 000 years ago include flaked stone artefacts, grindstones, ground ochre pieces and hafted edge-ground axes (Brockwell *et at*. 1995). More recent stone artefacts (approximately 5000 years ago) include finely worked small stone points and steep-edged chisels, while organic artefacts (from approximately 7000 years ago to present) include tools made from bone, wood and shell (Brockwell *et al.* 1995).

During the last thousand years, freshwater floodplains developed and created plentiful resources able to support higher levels of human occupation, and as such extensive scatters of stone artefacts are found on the floodplain. Stone artefacts such leilira blades (large points) and use-polished flakes appear during this period. Furthermore, organic materials such as wooden, fibre, bone and shell artefacts and the food remains of plant and bone are preserved in Kakadu National Park (Brockwell *et al.* 1995).

Fish Traps

Fish traps made from stone or basketry are believed to pre-date the arrival of Europeans (Hiscock and Kershaw 1992). Within Kakadu National Park, permanent fish traps have been found on the

Wildman River. Examination of these traps provides information on the hunter-gatherer society of Kakadu National Park prior to European arrival and influence.

Dugout Canoes

Dugout canoes were produced by cutting down a large tree and hollowing out a canoe from the trunk, a process observed by Baldwin Spencer in 1900 (Spencer 2009). Several dugout canoes have been discovered in Kakadu National Park, including some retrieved from the banks of the East Alligator River that have been preserved as cultural heritage items.

Significant Sites

Sites of cultural significance include areas that relate to the activities that took place during the creation era and the travels of the first people, significant rock art and occupation sites, burial sites, ceremonial sites, story places, increase sites, dreaming places and others (Brockwell *et al.* 1995, Brockwell *et al.* 2001). Dreaming places may be named after animals and may be significant for the reproduction or control of the relevant species (Brockwell *et al.* 1995). For example, wetland sites of Kakadu National Park include Whistle Duck, Goanna, King Brown, Hawk, Gecko, Barramundi and Turkey Dreamings. The maintenance of these sites is important for the continuation of each these species and certain Bininj may have specific responsibilities related to these Dreamings. Cultural protocols and totems may also place restrictions on the ability of some Bininj to eat certain species of animal.

3.9 Conceptual Models

Several conceptual models have been prepared to support this ECD, in particular to illustrate the interaction of critical components and processes to produce ecosystem services/benefits.

In seeking to logically characterise the broad range of wetland habitats present in Kakadu National Park, the models reflect: the coastal and estuarine areas that are characteristic of the northern areas of the site around the mouths of the major rivers; the wetland environments within the floodplains themselves which link the estuarine and freshwater habitats; and the freshwater dominated wetland systems associated with the upper catchment of the floodplain leading into the escarpment and the Stone Country.

Figure 3-26 provides an overview of the locations of wetland conceptual models presented in the ECD, noting the selection of the representative environments that have been chosen to demonstrate the interaction of critical ecosystem components, processes and services.

Figure 3-27 depicts the estuarine shoreline and island habitats that are characteristic of those wetlands found at and around the mouth of the South Alligator River. The wetland environments within this area are strongly influenced by tidal processes, noting the remarkable diversity of wetland environments (and associated ecosystem services) supported by Field Island.

Figure 3-28 and Figure 3-29 depict the floodplain wetland habitat characteristic of the South Alligator River near the tidal interface of the River with the Yellow Water area. Seasonal models have been presented (dry season and wet season) to illustrate the changes to use of the site during the seasonal cycle by waterbirds, crocodiles and other key wetland fauna. In the tropical monsoon environments of Kakadu National Park, these species and groups are heavily influenced by water levels, rainfall and other climatic conditions which control key life cycle processes such as migrations and breeding.

Figure 3-30 depicts the freshwater wetland habitats characteristic of the upper catchment of the South Alligator and Magela Floodplains, leading through the monsoon forests into the escarpment and the Stone Country. As outlined in the critical services section, the pool habitats within the escarpment are particularly notable in this region of the Park, supporting a range of endemic invertebrate and fish species, freshwater crocodiles and various waterbird species.

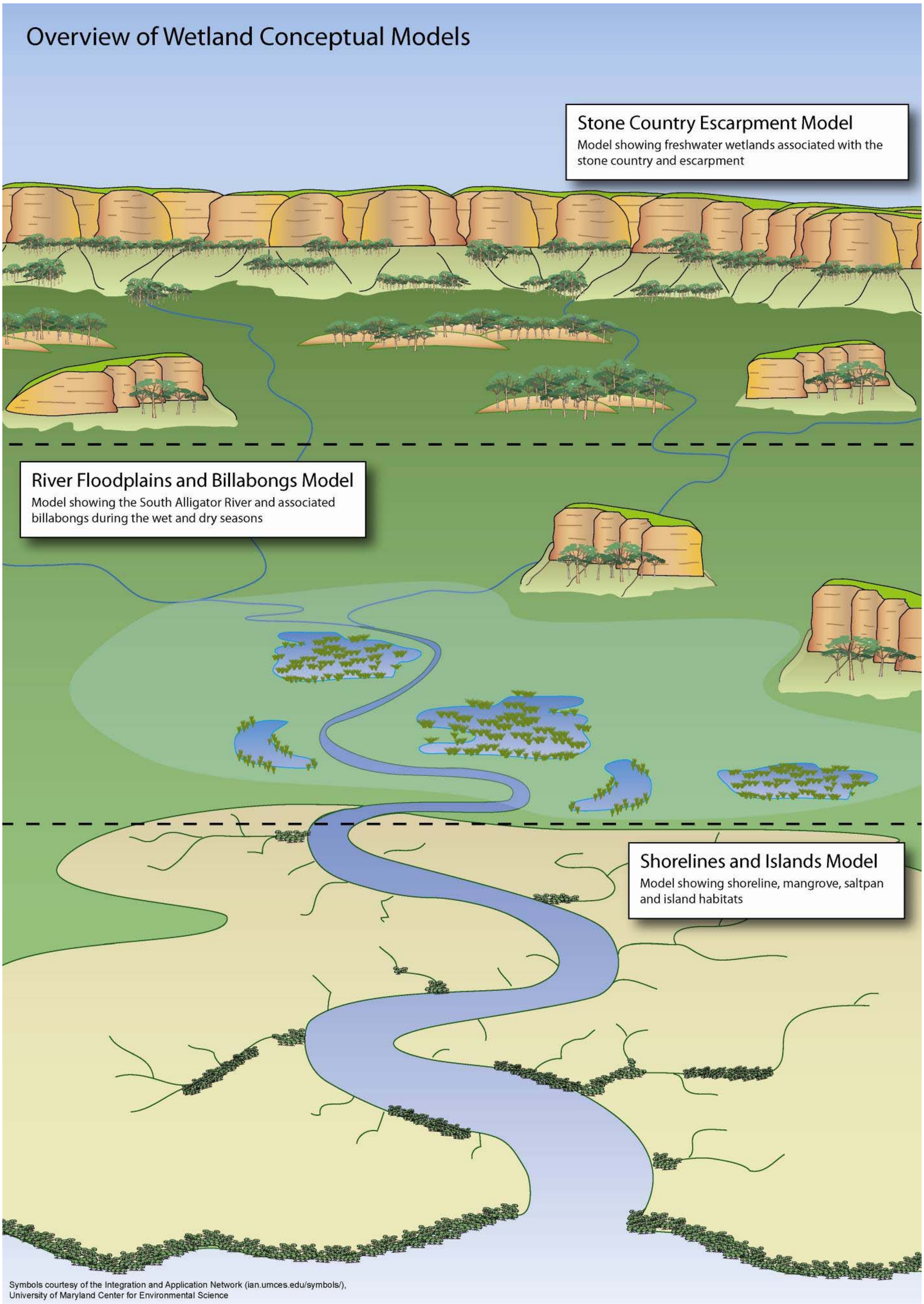

Figure 3-26 Overview of wetland conceptual models

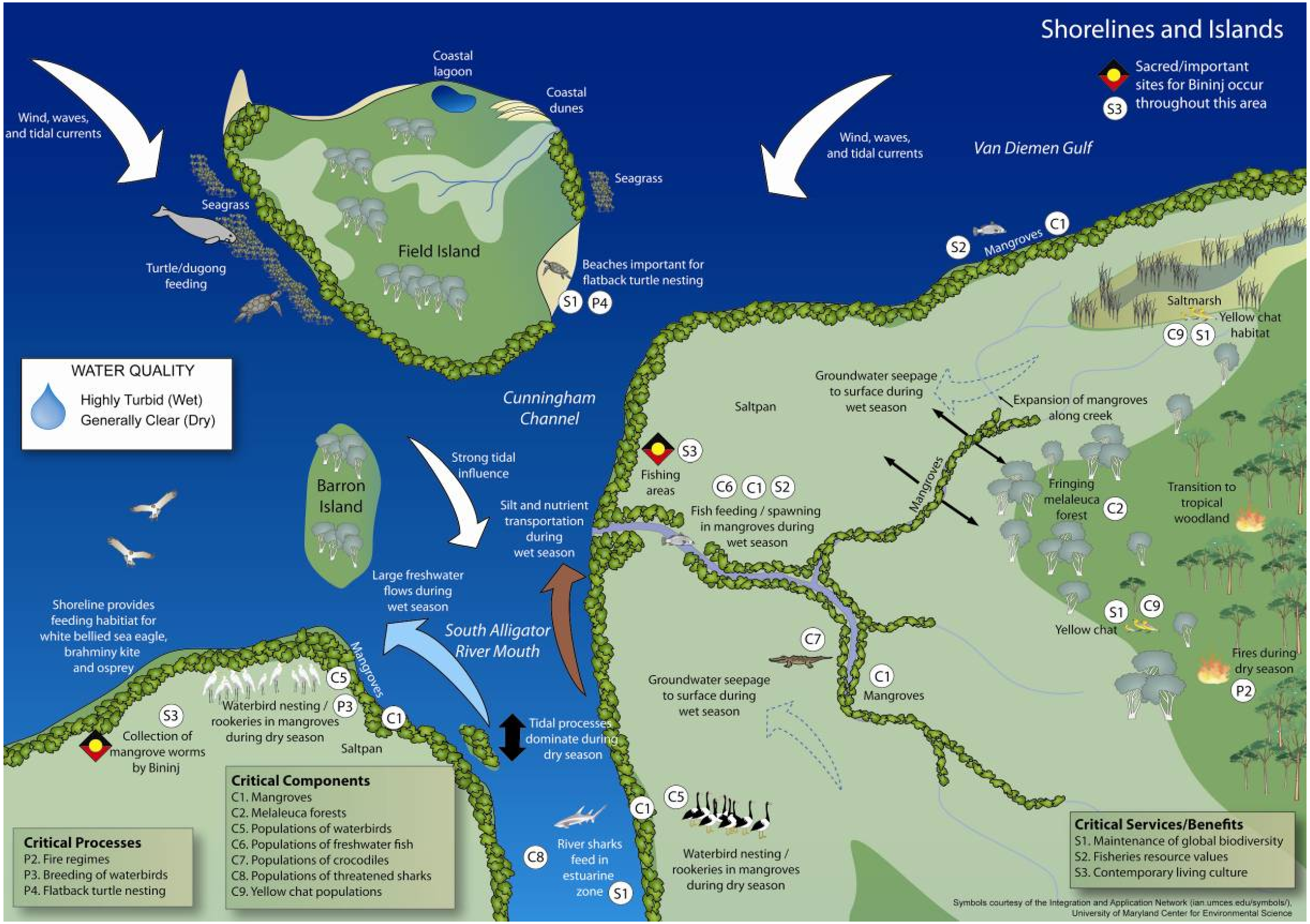

Figure 3-27 Shoreline and island conceptual model

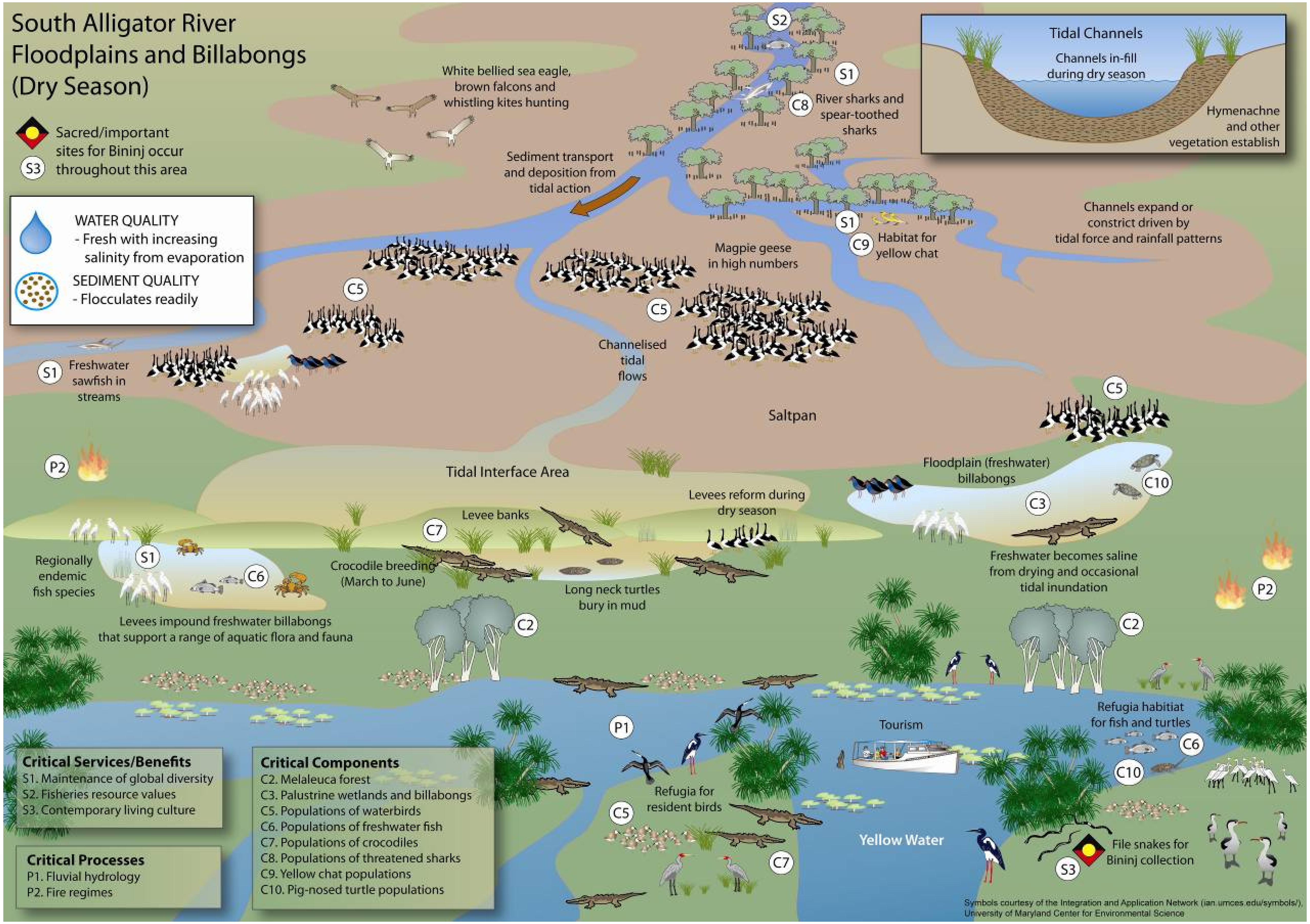

Figure 3-28 River floodplains and billabongs (dry season) conceptual mode

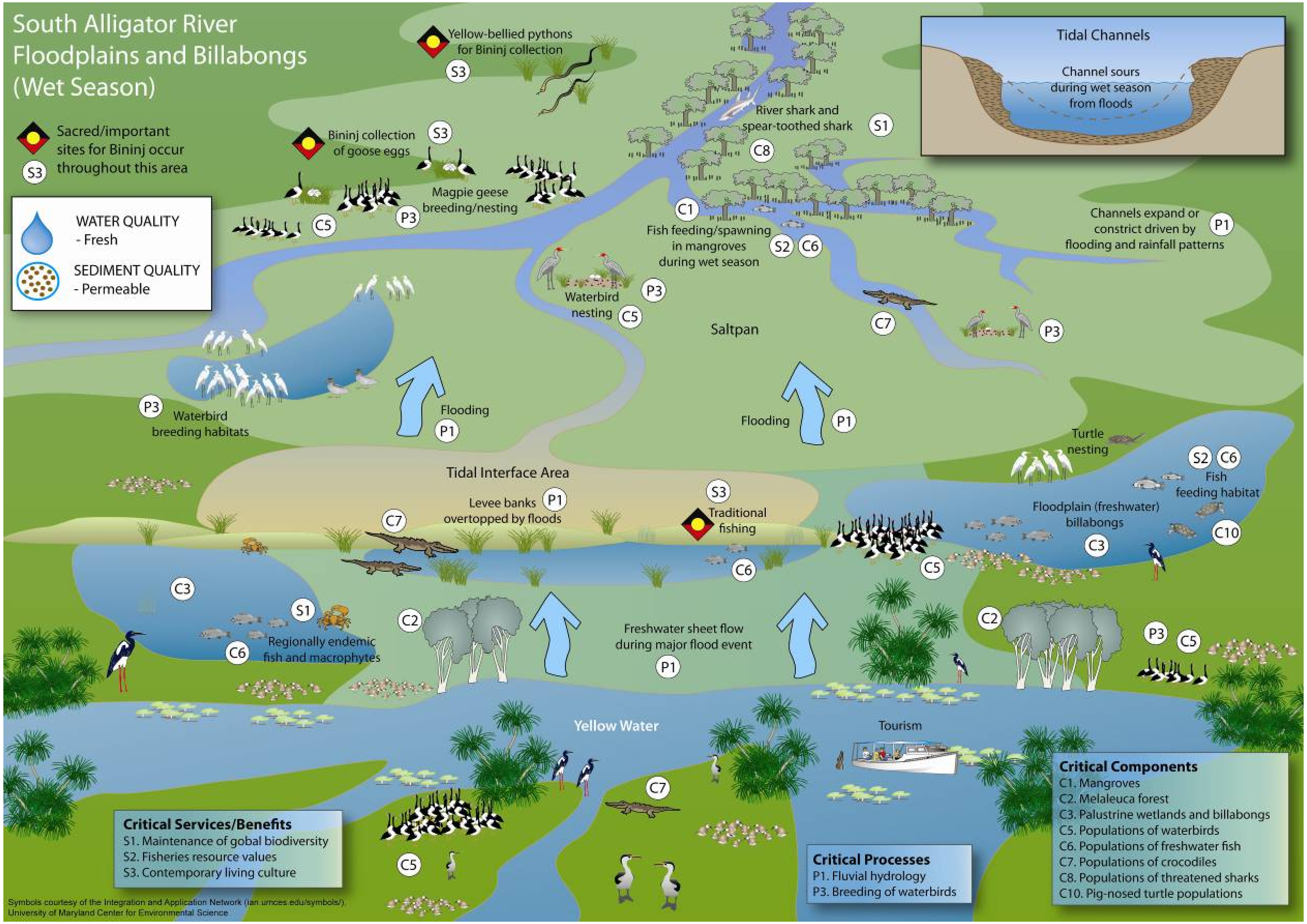

Figure 3-29 River floodplains and billabongs (wet season) conceptual model

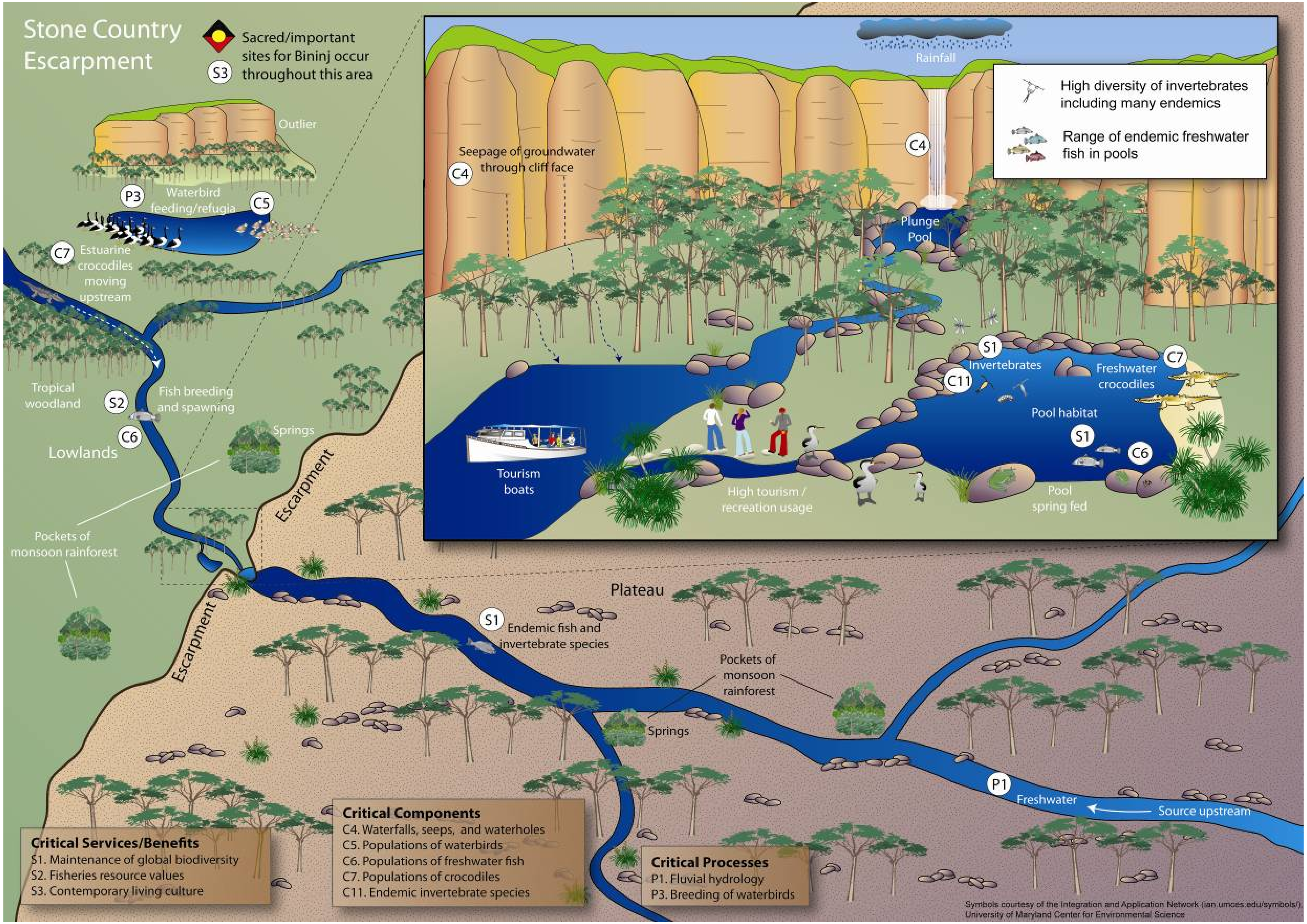

Figure 3-30 Upper catchment, escarpment and stone country conceptual model

4 LIMITS OF ACCEPTABLE CHANGE

4.1 Background

A key requirement of the ECD is to define the limits of acceptable change (LACs) for the critical components, processes and services/benefits of the wetland. LACs are defined as 'the variation that is considered acceptable in a particular measure of feature of the ecological character of the wetland' (DEWHA 2008). The LACs may equal the natural variability or may be set at some other value. LACs are based on quantitative information from relevant monitoring programs, scientific papers, technical reports, or other publications and information about the wetland or input from wetland scientists and experts.

Consistent with the above, the approach taken for the identification of LACs for the Kakadu National Park Ramsar site has been the following:

- to assess natural variability and provide limits of acceptable change for each of the critical services/benefits and to identify, where relevant, particular aspects of the service for which LACs have been derived, and
- to assess natural variability and provide LACs for critical wetland ecosystem components and processes specifically in the context of those wetland species (for example, species of conservation significance), populations (for example, waterbirds, fish) and habitat types (for example, seagrass, *Melaleuca*) that underpin the critical services/benefits.

It should be noted that in deriving the LACs as part of the current study, there are significant data and knowledge gaps and as a result, there are high levels of uncertainty associated with deriving the limits. As such, the LACs should be regarded by the site manager and other users of the document as being based on current knowledge and best professional judgement at the time of preparation of this ECD document, but need to be subject to further expert review over time and evaluated as knowledge about the site and it's ecological character improves.

In interpreting and assessing compliance with the LACs, a change to ecological character will generally be deemed to have occurred where an LAC has been exceeded. In most cases this will need to be determined through monitoring of the extent and condition of key wetland parameters (refer Section 7.2) and may require several sampling episodes in order to determine that the change is not part of broader natural variability of the system (for example, LACs based on a percent reduction in the use of the site by waterbirds based on successive counts of waterbirds over a specified time period).

It should also be noted that there may be a range of processes occurring outside of the site that could affect the exceedance of a particular LAC; for example, the populations of migratory species that use the site. As such, in the future evaluation of LACs it is important to determine if the underlying reason for the exceedance of an LAC is attributable to natural variability, related to anthropogenic impacts on or near the site or alternatively a result of anthropogenic impacts off the site (for example, lack of available breeding habitat for migratory birds in the northern hemisphere).

4.2 Derivation of Limits of Acceptable Change

In developing LACs as part of this ECD, a number of approaches were adopted, using existing data sets and information as well as national, state and local guidelines (see also Appendix B.2).

4.2.1 Natural Variability and Probability Based LACs

Defining Baseline Conditions

As outlined in the National Framework, it is most preferable for LACs to be based on the known natural variability (over time) of a parameter. The LAC can then be set at the upper and lower bounds of that natural variability profile in the time period leading up to Ramsar site declaration. However, in most cases such data are unavailable or incomplete.

Recognising these information gaps, particularly with respect to natural variability prior to listing, we have adopted the following hierarchy (in order of preference) for establishing baseline conditions and natural variability:

1. Empirical data (pre-listing) data describing natural variability prior to site declaration; or
2. Empirical data (post-listing) for parameters that are unlikely to have substantially changed since listing; or
3. Empirical data/qualitative data for parameters that may have changed since listing, but represent the only available data for establishing 'baseline conditions'.

Where there are no data (or very few data), this has been identified as an information gap and a recommended LAC has been provided that could be used, should data become available as result of future studies.

Defining Baseline Data Quality

In characterising the baseline information used in deriving LACs, the following typology has been used:

- Level A – This LAC has been developed from data and/or information (such as bird count data, fisheries catch data or similar) that has been reviewed by the authors and deemed to be sufficient for setting an LAC. This type of LAC is typically derived from long-term monitoring data;
- Level B – This type of LAC is derived from empirical data, but is unlikely to describe the range of natural variability in time. This can include two sub-types:
  - Repeated measurements but over a limited temporal context;
  - Single measurement (no temporal context) of the extent of a particular habitat type, abundance of a species or diversity of an assemblage;
- Level C – This type of LAC is not based on empirical data describing patterns in natural variability. This can include two sub-types:
  - Based on a published or other acceptable source of information, such as personal communication with relevant scientists and researchers, or is taken from referenced studies as part of management plans, journal articles or similar documents;

- Where there are no or limited data sets and a lack of published information about the parameter, and the LAC has been derived based on the best professional judgement of the authors.

The LAC tables below provide a LAC quality rating incorporating both the baseline data characteristics (see Defining Baseline Conditions above) and data quality (Level A, B or C).

Measures Used to Describe LACs

Depending on the LAC parameter under consideration, several types of measures may be used to describe natural variability:

- Percentile values. The use of percentile values allows for some change in the measured parameter, but still within the range of natural variability. Common examples of this type of LAC include water quality and biological indicator guideline values derived from statistical analysis of reference datasets. This approach is conceptually similar to the approach used for assessing water quality guideline values (for example, ANZECC/ARMCANZ 2000). Refer to Table 4-1 for an outline of the approach used to define percentile-based LACs.
- An allowable proportional change relative to a baseline value. While the use of percentile values to describe natural variability (and therefore LACs) is typically preferred, this is not always possible due to data limitations (such as insufficient baseline data to derive percentile values), and/or in some cases it is not meaningful to use percentiles due to the pattern in variability of the measured parameter (for example, the extent of some habitat types which show low natural variability). Similar to the approach used to define percentile-based LACs, professional judgement was used to set 'proportional change' based LAC values, based on criteria outlined in Table 4-1.
- **Broad Ecosystem State and Function**

This type of LAC is based on a broad change in an ecosystem from one state to another or on the basis of the wetland continuing to provide a particular function (such as provision of breeding habitat). An example of this type of LAC is a change in a particular wetland from a freshwater system to a brackish water system. This type of LAC has the advantage of encompassing a variety of indicators, and specifically addresses ecosystem end-points that can be directly linked to high level critical components and services. This type of LAC is particularly relevant where there is a lack of data and information to support a more quantitative LAC about ecological response or threshold.

Table 4-1 Statistical measures describing LACs

Degree of change	Description	Percentile values	% change
No change	• Parameters where any change would be considered unacceptable. • Parameters that show low natural variability and where even a small change would lead to a change in ecological character.	Same measure used to derive baseline. No significant change.	0% change
Small	• Within the range of natural variability; • Small to moderate variations from median baseline are acceptable, as: o Parameter has inherent low natural variability; and o Is considered to represent a direct measure of a critical service/benefit or component (e.g. bird abundance).	Upper = 80th Lower = 20th	5% change
Moderate	• Within the range of natural variability; • Moderate deviations from median baseline are acceptable, as: o Parameter has inherent moderate to high natural variability; and o A change in the parameter may not necessarily translate to an ecologically meaningful change in character. These are typically critical process-based LACs.	Upper = 90th Lower = 10th	10% change
Large	• At or outside the range of natural variability; • Large deviations from median baseline are acceptable, as: o Parameter has inherent high natural variability; and o A change in the parameter may not necessarily translate to an ecologically meaningful change in character. • These are typically: o Not direct measures of critical service/benefit, component or process-based LACs, but rather broad proxy indicators of ecosystem condition; or o Are critical service/benefit, component or process-based LACs where some degree of change outside natural variability is not considered to result in major change to ecological character.	Values outside the range of minimum and maximum baseline.	>20% change

4.3 Summary of Limits of Acceptable Change

Table 4-2 lists the LAC indicators relevant to each critical component process and service/benefit, and Table 4-3 outlines the specific LACs. For each LAC indicator outlined in the Table 4-3, the following information is provided: (i) the degree of acceptable change based on the typology outlined in Table 4-1 (refer to Appendix B for details); (ii) LAC values describing the degree of allowable change (relative to baseline conditions – see Appendix B) in the short-term (within 20 years of ECD preparation) or the long-term (greater than 20 years of ECD preparation); (iii) the spatial and temporal scale at which measurements must be undertaken to assess the LAC; (iv) data quality rating for baseline data and (v) secondary critical component, process and service/benefits addressed by the LAC. Short-term LACs should be reviewed to determine their potential applicability in subsequent periods (that is, post 2030).

As shown in Table 4-3, in most cases, the LACs in the current study have been subjectively derived (level 3) based on the best scientific judgement of the authors. This is due to:

- a largely incomplete data set for key parameters such as waterbird usage, fish usage and environment condition (both geographically and temporally) since listing, and
- the general lack of scientific knowledge about the response of particular species and habitats to multiple stressors (for instance a combination of water flows, salinity and habitat availability).

Further discussion on these information gaps is provided in Section 7.1 of this document.

Table 4-2 Critical components, processes and services/benefits, and relevant LAC indicators

Critical Element	LAC
Critical Components	
C1 – Mangroves	1
C2 – *Melaleuca* Forests	2
C3 – Palustrine Wetlands and Billabongs	3
C4 – Waterfalls, Seeps and Waterholes	4
C5 – Populations of Migratory and Resident Waterbirds	10, 11, 12, 13
C6 – Populations of Freshwater Fish	15
C7 – Populations of Freshwater and Saltwater Crocodiles	16, 17
C8 – Populations of Threatened Sharks	5
C9 – Yellow Chat Populations	8
C10 - Pig-nosed Turtle Populations	6
C11 – Locally Endemic Invertebrate Species	9
Critical Processes	
P1 – Fluvial Hydrology	18
P2 – Fire Regimes	20
P3 – Breeding of Waterbirds	19
P4 – Flatback Turtle Nesting	7
Critical Services/Benefits	
S1 – Maintenance of Global Biodiversity	5, 6, 7, 8, 9
S2 – Fisheries Resource Values	14, 15
S3 – Contemporary Living Culture	21, 22

Table 4-3 Limits of acceptable change (LAC)

Number	Indicator and Primary critical Component / Process/Service for the LAC	Acceptable Change (Short term or long term)	Limit of Acceptable Change	Spatial scale/temporal scale of measurements	Underpinning baseline data	Secondary critical components/ processes/services addressed through LAC
1	Reduction in mangrove extent (Component 1).	Large change (short term)	Mangrove extent will not decline by greater than 25 percent of the following baseline values: Stage I (1984 closest date prior to 1980 listing) • EAR = 21 km^2 Stage II (1991 closest date to listing) • SAR = 36 km^2 • WAR = 42.5 km^2 • Wildman = 14 km^2 Note: An increase in mangrove does not in itself represent a change in character unless other components or services/benefits significantly affected.	• Minimum three sample events separated by at least two year intervals. • Measured over a 20 year period from date of ECD preparation.	1A	Service 3
2	*Melaleuca* forest extent (Component 2).	Large change (short term)	The number of *Melaleuca* trees at the Magela floodplain will not decline by greater than 50 percent of baseline values of Riley and Lowry (2002) for the year 1996 (24 704 trees).	• Minimum three sample events separated by at least two year intervals. • Measured over a 20 year period from the date of ECD preparation.	2A	Service 3
3	Palustrine wetlands and billabongs (Component 3).	No change (short term)	No permanent loss of billabongs in the South Alligator River catchment (as mapped by BMT WBM 2009) as a direct result of anthropogenic changes in hydrological or geomorphological processes.	• As observed on an annual basis. • Measured over a 20 year period from the date of ECD preparation.	2C	Component 5, 6, 7 and 10 Process 1, 3 Service 2 and 3
4	Waterfalls, seeps and waterholes (Component 4)	No change (short term and long term)	No drying of any perennial seeps and permanent waterholes.	Absolute value.	1B	Component 5, 6, 7, 10 and 11 Process 1 Service 1 and 3
5	Spear-tooth shark and northern river shark distribution and abundance (Component 8).	No change (long term)	The site continues to support spear-tooth shark in the long-term. Wildman and East, West and South Alligator Rivers continue to support northern river shark in the long-term.	• Absolute value. • Absence of these species during three successive sampling occasions (separated by at least one year intervals) will represent an exceedance of LAC.	3B	Service 1

6	Pig-nosed turtle distribution and abundance (Component 10).	Large change (short term)	Within the known core habitat of this species (as outlined in Georges and Kennett 1989; see Figure 3-10), the average density of pig-nosed turtle will not fall below 13.5 turtles/ha (30 percent reduction of minimum baseline value of 22.5 turtles/ha). Note that Stage specific data are not available, and baseline values were taken post-Ramsar site listing.	• Minimum three sample events separated by at least two year intervals. • Measured over a 20 year period from date of ECD preparation.	2B	Service 1
7	Flatback turtle nesting (Service 1).	Small change (short term).	The average number nesting attempts at core turtle nesting areas on Field Island, as measured over a one week period during the peak breeding period, must not fall below 0.8 attempts/night in three successive years (20 percent reduction in the minimum baseline value of one attempt a night during the peak breeding season). NB: baseline values were taken post-Ramsar site listing.	• Minimum five sample events. • Measured over a 20 year period from date of ECD preparation.	2A	Process 4
8	Yellow chat distribution and abundance (Component 9).	Large change (long term)	Floodplain habitats of the site continues to support yellow chat in the long-term.	• Absolute value. • Absence of yellow chat at known sites on South Alligator River floodplain (north of Arnhem Highway) during three successive dry season sampling events (separated by at least one year intervals) over any 20 year period will represent an exceedance of LAC.	3C	Service 1
9	Local endemic invertebrate species distribution and abundance (Component 11).	No change (short term or long term)	As a minimum, sites at which each species has previously been recorded will continue to provide habitat for these species, unless it can be demonstrated that the species (i) can re-establish naturally and/or (ii) shows great variability in its presence within a site.	• Absolute value. • Absence of any endemic species during three successive sampling occasions (carried out in appropriate seasons and separated by at least one year intervals) over any 20 year period will represent an exceedance of LAC.	2B	Service 1

10	Waterbird abundance (excluding migratory shorebirds) (Component 5).	Moderate change (short term, individual floodplain context)	Average abundance of the most common species (magpie geese, wandering whistling-duck and plumed whistling-duck) will not fall below the corresponding minimum recorded seasonal values of Morton *et al.* (1991) for Magela, Nourlangie and East Alligator River floodplains on more than 30 percent of sampling occasions over a 20 year period.	• Recommended baseline monitoring program should be based on aerial survey protocols of Morton *et al.* (1991) for Magela, Nourlangie and East Alligator River floodplains. The survey coverage should be expanded to include the South Alligator River floodplains (esp. Boggy Plains). Based on a ten year cycle, the recommended program should comprise a minimum three annual sampling periods, each separated by at least one year. Each annual sampling period is comprised of one late dry season and one wet season survey. • LAC based on at least three annual surveys measured over a 20 year period from date of ECD preparation.	2B	Process 3
11	Waterbird species (greater than one percent threshold; excluding migratory shorebirds) - magpie geese, wandering whistling-duck, plumed whistling-duck, radjah shelduck, pacific black duck, grey teal, brolga, and black-necked stork (Component 5).	Moderate change (short term)	Insufficient current, systematically collected baseline data. Long-term LAC to be confirmed on completion of data collection as part of the recommended baseline monitoring program for Indicator 10 above. The following LAC is recommended in the interim: Average abundance of each species will not fall below the corresponding minimum recorded seasonal values of Morton *et al.* (1991) for Magela, Nourlangie and East Alligator River floodplains on more than 30 percent of sampling occasions over a 20 year period.	• For recommended baseline program, spatial and temporal characteristics as for Indicator 16 above. • LAC based on at least three annual surveys measured over a 20 year period from date of ECD preparation. An annual survey comprises a representative dry and wet season event.	2B	Process 3
12	Migratory shorebird distribution and abundance (Component 5).	Moderate change (short term and long term)	Insufficient current, systematically collected baseline data. Should an adequate baseline be established, limits of acceptable change could be calculated based on the range of variability. In the interim, and as a minimum, sites at which each migratory shorebirds have previously been recorded (as per Chatto 2003) will continue to provide habitat for these species.	Recommended baseline monitoring program should include: • A combination of aerial and ground surveys. • Representative coverage of primary habitats, i.e. intertidal coastline (including lower estuary areas), floodplain wetlands and grasslands. A minimum of three annual sampling periods, each separated by at least one year, and within a 20 year period. Each annual sampling period is comprised of two seasonal survey events, i.e. a late dry and a late wet season survey.	2B	Process 3

13	Migratory shorebird species (greater than one percent threshold) - marsh sandpiper, little curlew, common sandpiper, Australian pratincole, and sharp-tailed sandpiper (Component 5).	Large change (long term)	Average abundance of each species (derived from at least three annual surveys over a 10-year period) does not fall below the 20th percentile baseline value, or below one percent of their relevant flyway population, due to altered habitat conditions within the site. Until completion of a suitable baseline monitoring program (and determination of LACs), the following interim LAC is recommended: one or more species (whose population is currently known to exceed the one percent threshold) no longer occurs within the site. For LACs, it must be clearly demonstrated that such changes occur outside of the boundaries of what is considered to be natural variability and/or (and in regards to migratory shorebirds) not underpinned by significant external factors which are known to have impacted on a species within other parts of the flyway for the species (staging sites or breeding grounds).	Recommended baseline monitoring program should target the following areas: • Coastline, including lower reaches of major rivers (about 10 km from river mouth) – marsh sandpiper, common sandpiper, and sharp-tailed sandpiper. • South Alligator River floodplains (east to Boggy Plains and Billyangardee Spring) - marsh sandpiper, little curlew, Australian pratincole, and sharp-tailed sandpiper. Recommended program should comprise a minimum three annual sampling periods separated by at least one year (and within a 10 year period). Each annual sampling period is comprised of two seasonal survey events, one during late-March to mid-May (wet season and corresponding to northward migration), and the second, during mid-September to mid-November (late dry-season and corresponding to southward migration). LAC based on at least three annual surveys measured over a 20 year period from date of ECD preparation. An annual survey comprises a representative dry and wet season event (as described above).	2B	Process 3
14	Barramundi abundance (Service 2).	Large change (short term)	The average abundance of barramundi will not fall below the minimum recorded values of Humphrey *et al.* (2005) at both Sandy and Mudginberri Billabongs on more than 50 percent of sampling occasions over a 20 year period. Note: Population data are available for Yellow Water (estimated population of 6000 fish in 1994). In the absence of information describing temporal patterns in abundance, there is insufficient data to establish an LAC for barramundi population size.	• Minimum six sample events separated by at least one year. • Measured over a 20 year period from date of ECD preparation.	2A	Service 3
15	Freshwater fish abundance in billabongs (Component 6).	Large change (short term, whole of site scale)	The average abundance of freshwater fish species will not fall below the minimum recorded values of Humphrey *et al.* (2005) at both Sandy and Mudginberri Billabongs on more than 50 percent of sampling occasions over a 20 year period.	• Minimum six sample events separated by at least one year. • Measured over a 20 year period from date of ECD preparation.	2A	Service 2 and 3

16	Saltwater crocodile abundance (Component 7).	Large change (long term)	The average abundance of saltwater crocodiles will not fall below 35 000 individuals, which represents a 50 percent reduction in the 1994 estimated population.	• Minimum five sample events separated by at least one year. • Measured over a 20 year period from date of ECD preparation.	3A	
17	Freshwater crocodile abundance (Component 7).	Large change (short term, whole of site scale)	The average abundance of freshwater crocodile will not fall below the minimum recorded values of Parks Australia (Figure 3-18) on more than 50 percent of sampling occasions over a 20 year period.	• Minimum six sample events separated by at least one year. • Measured over a 20 year period from date of ECD preparation.	2B	
18	Surface water flows – annual flows (Process 1).	Large change (short term)	Baseline annual flow values vary over time scales measured in decades, and climate change is predicted to result in further major changes. In the interim the following is recommended until it can be refined: A greater than 20 percent change in the long-term mean annual flow constitutes an unacceptable change based on the following long-term average values: • East Alligator = 6.87 million ML/year • South Alligator = 5.75 million ML/year • West Alligator/Wildman = 0.815 million ML/year	• Measured over 20 year period. • Values measured at existing gauging stations near mouth of each river.	1A	
19	Critical life stage processes (Process 3): • Feeding and roosting habitat for 53 waterbird species (including 29 migratory shorebird spp.). • Dry weather refuge for large aggregations of waterbirds at the Magela and Nourlangie floodplains. • Feeding, breeding and dry weather refuge sites for species listed in Service 3.	Large change (short term)	• Exceedance of LACs in the *Species and Habitat* LAC Table; OR • Based on expert opinion, the site no longer provides adequate refuge function for important flora and fauna species and populations; OR Based on expert opinion, critical life-cycle processes identified in column 1 (e.g. known feeding sites, roosting sites, breeding sites, etc) have either substantially diminished (in terms of frequency or extent of usage) or are otherwise no longer being supported (relative to natural variability).	Absolute value.	3C	

20	Fire – frequency (Process 2).	Large change (short term)	• The area of wetland burnt per year within individual habitat types will not exceed maximum recorded baseline values outlined in Gill *et al.* (2000) more than twice over a 20 year period. Baseline values may not represent optimal fire regimes. These values should be reviewed to determine whether other elements of ecological character could be affected by through the maintenance of these regimes.	• 20 year measurement periods from time of ECD preparation. • Whole-of-site spatial scale and within plateau, lowland and floodplain habitats.	1A	
21	Loss or damage to rock art sites, archaeological sites and materials (potentially due to human interference, feral animal damage, weathering, environmental degradation and natural processes including vegetation growth, storms and tidal inundation of flood plains) (Service 3).	Medium change (short term) No change	Changes to the following indicators are considered unacceptable: • A greater than 10 percent reduction in the number of recorded sites due to preventable damage (e.g. human interference, feral animal damage, weathering, environmental degradation) (NB: Kakadu National Park has 203 sacred sites recorded on its list of 5000 recorded cultural sites (with possibly another 2000 sites which have not yet been recorded) stored on a cultural database at Kakadu National Park Headquarters). • A greater than 10 percent reduction in the number of sites managed/maintained (outlined in the cultural database at Kakadu National Park Headquarters) due to preventable damage. No damage to representative and high priority sites (to be identified through Kakadu National Park's Cultural Heritage Program).	Absolute measure.	2B	
22	Indigenous 'living culture' (including the body of Traditional Ecological Knowledge, Bininj languages, traditional fire and land management practices, traditional resource use) (Service 3).	N/A	Due to the lack of quantitative data regarding 'living culture' attributes, the limits of acceptable change are unable to be defined quantitatively. However a change in the ability of Bininj to own, occupy, access and use the land and resources of Kakadu National Park could result in a loss of 'living culture'. A change in the ability of Bininj to use and transmit Bininj cultural practices, knowledge, language and spirituality could also result in a loss of 'living culture'**	N/A	N/A	

Note that where particular areas have been quantified, these are based on the best available data/mapping and should be revised if a more appropriate baseline dataset is derived.

** These cultural elements could be monitored by Bininj and reported through cultural heritage workshops to discuss indicators of ‘living culture’, including: use and transmission of languages, cultural practices, cultural knowledge; access to land and resources; and the ability to undertake spirituality practices

N/A = no available data

5 OVERVIEW OF CURRENT AND FUTURE THREATS

The threats to the ecological character of the Kakadu National Park Ramsar site varies greatly across multiple spatial and temporal scales and in terms of their potential severity. Major threats are summarised in Table 5-1 and are discussed below. In characterising the key threats outlined in Table 5-1, the consequence of individual threats were assessed based on categories presented in Table 5-2.

Table 5-1 Summary of major threats to the Kakadu National Park Ramsar site

Threat	Potential impacts to wetlands	Consequence	Timing*
Proliferation/ introduction of exotic flora	Continuing impacts from presence and proliferation of key wetland weed species such as mimosa, salvinia, para grass and olive hymenachne.	Medium	Short- to long-term
Proliferation/ introduction of exotic fauna	Continuing impacts from cane toads, pigs, buffalo and other invasive species into wetland habitats and negative impacts on the populations of wetland-dependant species.	High	Short- to long-term
Climate change – Increased saltwater intrusion from sea level rise	Increased rates of saltwater intrusion and loss of predominant freshwater wetland areas; associated loss of species diversity and habitat and associated ecological and cultural values associated with these areas.	Medium to high	Medium- to long-term
Climate change – Changes to mangrove distribution from sea level rise	Increased proliferation of mangroves at the expense of saltmarsh and *Melaleuca* communities; possible loss of existing mangrove communities in foreshore and lower estuary zones due to increased sea level rise and water-logging; associated loss of species diversity and habitat and associated ecological and cultural values associated with these areas.	Medium to high	Medium- to long-term
Climate change – Changes to fire regime	Changes to rates of evaporation and increased drought conditions leading to change in wetland inundation regimes and increased risks of wetland damage from more intense fires.	Medium to high	Medium- to long-term
Tourism and recreational activities	Disturbance to flora and fauna; litter and waste production, water pollution, damage to archaeological sites/materials, restriction on private cultural activities, impacts to habitats by boats..	Low	Short- to medium-term
Mining activities	Release of radionuclides and other pollutants into surface and/or groundwater and associated ecological effects and possible human health effects in terms of bioaccumulation in bush tucker species, potential damage to culturally significant sites.	Low to medium	Short-term
Public safety and crocodiles	Continued diminishment of tourism and recreational values (e.g. swimming) as a result of presence of large crocodiles in high use areas.	Medium	Short- to medium-term
Damage to archaeological resources and rock art	Specifically human induced impacts including theft, vandalism and inappropriate development and tourism. Weathering, vegetation growth and feral animal, termite and fire damage.	Low to medium	Medium- to long-term
Living resource extraction	Impact on fish populations, loss of bush tucker resources, loss of application of traditional cultural practices; impact of poaching/ inappropriate hunting on wildlife and plant populations.	Low to medium	Medium- to long-term

*Timing: short term: about 1-2 years; medium term: about 5 – 10 years; long term: more than 10 years.

Table 5-2 Threat Consequence Categories

Consequence	Interpretation
High	• Irreversible impacts at the broad scale or regional scale • Medium-term impact at the broad scale
Medium	• Irreversible impact at a local scale • Medium-term impacts at the regional scale • Short-term impact at a broad scale
Low	• Irreversible impact at the individual scale • Medium-term impact at a local scale • Short-term impact at a regional scale

5.1 Exotic Flora

Weeds present an on-going threat to the values of the Ramsar site, primarily due to their ability to out-compete native plants, leading to displacement of food sources for fauna as well as bush tucker species. Additionally, weeds may change the structure of vegetation communities and fire regimes, thereby altering habitat suitability for functions such as waterbird nesting and roosting.

Walden and Gardener (2008) estimate that Kakadu National Park management's annual expenditure on weed prevention and control is approximately $1.2 million. Species of concern are listed in Walden and Gardener (2008), and key species are also discussed below and in Section 6.1.2.

Weeds are particularly problematic within the freshwater habitats of the Park (for example, Bayliss *et al.* 1997, Douglas *et al.* 2008). In particular, threats posed by exotic pasture grasses continue to increase. The predicted spread of para grass *Urochloa mutica* is expected to cause a range of negative impacts on freshwater wetlands including almost total displacement of native vegetation (Douglas *et al.* 2001). New outbreaks of olive hymenachne *Hymenachne amplexicaulis* are also notable, similarly displacing native floodplain vegetation (Douglas *et al*. 2008).

From a cultural heritage perspective, weeds including salvinia *Salvinia molesta*, olive hymenachne, para grass and mission grass *Pennisetum polystachion* have reportedly led to a decrease in hunting and fishing grounds. Decreased use of traditional hunting and fishing grounds can lead to reduced application and transmission of traditional ecological knowledge.

As described in Section 3.5.2, weeds have also led to changes in fire regimes, making it difficult to maintain Kakadu National Park's natural ecosystems through fire management based on traditional Bininj burning practices. Also as mentioned in Section 3.5.2, exotic grasses increase fuel loads and the intensity of fires, which may threaten native fauna such as turtles (Douglas *et al.* 2008) and fire sensitive flora species and/or propagules (Petty *et al.* 2008).

Principal future threats to ecological character from weed invasion relate to introduction of propagules (of weed species that are currently problematic or new species that may become problematic) from adjoining pastoral land on the Park's west, from Arnhem Land and from visitors.

5.2 Exotic Fauna

Exotic fauna will continue to be a threat in the absence of management intervention. Control options for large herbivores are generally restricted to broad-scale helicopter shooting campaigns. As part of the Kakadu National Park Feral Animal Management Program 2008-2009, approximately 468 helicopter hours were deployed and almost 11 000 large non-indigenous herbivores culled during that program (S. Atkins pers. comm. 2009; see Table 5-3). From year to year, extent and location of aerial culls can vary considerably (for example, 2008-2009 program was the largest in recent years and provided particular attention to the southern and western parts of the site; B. Salau pers. comm. 2009).

Despite feral animal management programs, efforts to control damage within the site are likely to be compromised by entry of animals from neighbouring regions where land managers either lack interest or funds to implement broad-scale control, have reservations given the lack of evidence for general density-damage relationships, or have fundamentally different management goals (Bradshaw 2008). Furthermore, for some species (for example, horses), there are competing cultural, ethical and political interests that render the decision to reduce non-indigenous animal densities controversial (Gardner *et al.* 2002; Director of National Parks 2007; Bradshaw 2008).

Cane toads *Rhinella marina* are a relatively recent arrival in Kakadu National Park, first recorded in 2001 but have since become well-established, and are likely to colonise every habitat type present (van Dam *et al*. 2002b). Cane toads are regarded as a potentially significant threat to many native fauna species within the site (Gardner *et al.* 2002; Director of National Parks 2007). Key concerns are linked to negative impacts arising from direct consumption, competition for resources, and toxic effects on toad predators (van Dam *et al.* 2002b; Bradshaw *et al.* 2007, also refer Section 6.1.2). There is currently no known method of cane toad control over large spatial areas (Director of National Parks 2007).

Impacts of exotic fauna are further discussed in Section 6.1.2.

Table 5-3 Summary of Aerial Feral Animal Management Program 2008-2009

Species	November 2008	May/June 2009	Total Cull
Pigs	3402 seen, 2881 shot	5001 seen, 4525 shot	7406
Horses	2175 seen, 983 shot	1629 seen, 1320 shot	2303
Donkey	633 seen, 533 shot	112 seen, 105 shot	638
Buffalo	138 seen, 75 shot	364 seen, 289 shot	364
Cattle	134 seen, 70 shot	153 seen, 11 shot	81
Total Cull	4542	6250	10 792

5.3 Climate Change

There have been several assessments of the implications of climate change for Kakadu National Park or elements thereof. The most substantive study to date was undertaken by Bayliss *et al.* (1997) which assessed the vulnerability of predicted climate change and sea level rise in the Alligator Rivers Region.

More recent assessments include the National Coastal Vulnerability Assessment Case Study of the South Alligator River Catchment (BMT WBM 2010) and the Implications of Climate Change for Australian World Heritage Properties: A Preliminary Assessment undertaken and published by the Australian National University in 2009 (ANU 2009). Climate change research relevant to the Park and wetland management has also been undertaken for some time by *eriss* as outlined in Bartolo *et al.* (2008).

Overall, the principal threats to the wetland values of the Kakadu National Park Ramsar site from climate change can be summarised as follows:

- increased rate and extent of saltwater inundation into freshwater coastal environments due to sea level rise and storm surge events
- response of mangrove communities to rising sea level, and
- more intensive fire regimes that eventuate due to hotter dry seasons and the resulting damage these hot fires have on monsoon forest.

5.3.1 Saltwater Intrusion into Freshwater Areas

A range of studies have been conducted to predict the impacts of sea level rise on saltwater intrusion processes with claims of a 50 percent loss of Kakadu National Park's freshwater floodplain wetlands based on a one to two degrees Celsius increase and a complete loss of wetlands from a two to three degree Celsius increase (Hare in Bartolo *et al.* 2008). Bayliss *et al.* (1997) indicated that all wetland areas in the region below four metres in elevation are assessed as being vulnerable to climate-induced changes.

A more recent and detailed study by the authors (refer BMT WBM 2010) used hydrodynamic and catchment modelling outputs to assess the increased risk of saltwater intrusion from sea level rise and extreme rainfall events on low-lying coastal wetlands in the South Alligator River catchment. The tidal channel and floodplain model indicated that the sea level rise predictions resulted in the most significant impact, as these increased water levels were efficiently propagated up the river to the tidal head (landward limit of the tidal component of the system). Storm surge impacts were less significant, both in the degree of increase and also because they are associated with cyclones which are expected to happen about once per year.

Interpretation of the tidal component results suggested increased tidal pressure on dendritic channels within the South Alligator River system. This may act to keep channels open for longer or force them to extend further. In addition, increased tidal flows and velocities are expected to occur due to an increased tidal prism. Resulting impacts may be dramatic, particularly if tide levels overtop river banks and/or levees. Significant changes may occur if a greater volume of tidal water flows onto the floodplain via the overtopped levees.

The study concluded that the combined effect of expansion of the dendritic channel system, together with increased levee overtopping is likely to result in increased saltwater intrusion during the dry season. Subsequently, there is an increased likelihood of nearby freshwater billabongs being impacted by saltwater intrusion. This response is considered more likely for areas already threatened by saltwater intrusion and areas adjacent to tidal/dendritic channels.

Based on the previous assessments, it is clear that more precise information on areas likely to be impacted will be required including detailed topographic survey data to calibrate hydrological and catchment models used to predict sea level rises. In this context, it should be noted at the time of preparation of this ECD a detailed study of saltwater intrusion associated with sea level rise and climate change had been recommended as part of the report of the House of Representative Commission of Inquiry on Climate Change and Coastal Management.

5.3.2 Mangrove Expansion

The response of macro-tidal estuaries to sea level rise is only partially understood, but it is clear that the current trend of mangrove expansion observed over the past 50 years in the Park will continue and expand under sea level rise scenarios, particularly in those marginal saltpan areas that are currently only receiving occasional tidal inflows. As outlined in Section 3.2.1 and 3.2.2, the impacts of this will be for mangroves to continue to replace salt marsh/pan and fringing *Melaleuca* communities, assuming that suitable habitat conditions exist (for example, bed levels are at a suitable height, creeks are adequately flushed etc.). Inversely, current mangrove communities along downstream tidal channels and in the lower reaches of the estuaries could be at risk from more permanent inundation and water logging if sea levels rise too quickly for the communities to naturally respond. This ‘drowning’ effect has not been specifically observed at broad-scales to date in the Park but is regarded as a potential threat, particularly given the more extreme sea level rise predictions that are emerging.

5.3.3 Changes to Fire Regimes

It is generally accepted that increased frequencies and intensities of fire associated with higher temperatures, longer dry seasons and increased weed prevalence threaten the values of the Ramsar site (for example, refer Section 5.1). However, perceptions and opinions about over-burning in upland areas versus the lack of burning in floodplain areas continue to be areas of contention between stakeholders (D. Lindner pers. comm. 2009)

5.4 Tourism and Recreational Activities

The management challenge for Kakadu National Park is to maintain a balance between providing opportunities for the appropriate use, appreciation and enjoyment of the Park by a diversity of visitors, and protecting the rights and interests of Bininj and the natural and cultural values of the Park (refer Director of National Parks 2007). Specific threats to Ramsar values from visitor and recreational activities include:

- disturbance to fauna species, particularly waterbirds, at feeding and nesting sites or during breeding season
- recreational boating activities that can damage foreshore flora, promote salt water intrusion through alterations to hydrology and foreshore vegetation, spread weeds and feral animals, disturb fauna and introduce a range of pollutants through boat sewage, boat wash and subsequent erosion, leaching of anti-fouling compounds, fuel spills etc. Boating activities are also a concern for Bininj as these waterways can be important hunting and fishing grounds, and the protection of ecosystems ('caring for country') is an important aspect of Bininj culture, and
- camping and recreational fishing leading to problems associated with litter, water pollution, fire, removal and damage to native vegetation, and associated soil erosion and soil compaction.

In general, the management regime implemented by Parks Australia is such that the potential impacts from tourism and recreation activities on ecological character are considered to be a low risk.

5.5 Mining Activities

The main risk identified for ecosystems surrounding the uranium mine sites in the Alligator River Region is from the dispersion of mine waste waters to streams and shallow wetlands, including contamination with radioactive substances (Supervising Scientist 2002). In particular, high rainfall during the wet season often results in the need to release low-level contaminated runoff stored in on-site water bodies (van Dam *et al.* 2002a). While toxicity tests have been conducted to investigate the effect of uranium on invertebrate and vertebrate species (van Dam *et al.* 2002a, Hogan *et al.* 2005), historical water quality monitoring in Magela Creek showed that uranium concentrations are approximately an order of magnitude lower than the site-specific water quality trigger value (established by the Supervising Scientist), indicating that the risk to the downstream environment from controlled waste water release may be negligible (Hogan *et al.* 2005).

Since the major tailings water leak from the Ranger mine that occurred in the 1999-2000 wet season (refer Supervising Scientist 2000), a monitoring program using biological, chemical and radiological techniques to monitor and assess impacts upon ecosystems and humans arising from mining activities has been developed and implemented at Ranger and Jabiluka (refer Supervising Scientist 2002). This program has been undertaken since that time with an annual review of key knowledge needs and monitoring. In general, the precautionary approach and extensiveness of the program are such that there is a strong level of confidence that any impacts from tailings water leakage or other impact would be detected and acted upon. Nonetheless, the impacts from mining operations remain a salient threat to the ecological character of Kakadu National Park at least in the short term for the remaining duration of mining activities.

In this context, it is noted that historical mining sites in the South Alligator River region continue to be monitored and rehabilitated, but to date, the general view of the Knowledge Management Committee was that these sites are not thought to represent a threat to future ecological character.

5.6 Public Safety and Crocodiles

Following the protection of crocodiles in the 1970s, the abundance of saltwater crocodiles *Crocodylus porosus* has increased within Kakadu National Park (refer Section 3.3.7), thereby increasing the likelihood of crocodile attacks on humans. However, only two fatal crocodile attacks have occurred within the Park over a period of 27 years during which an estimated 3.5 million people visited the Park (SMH 2004). The emphasis of crocodile management within the Park is to educate visitors about crocodiles and their dangers through brochures, signs and advice. Should an increase in crocodile attacks occur, it is possible that visitor numbers may be affected. This may deter some visitors, but may attract others.

5.7 Damage to Archaeological Resources and Rock Art

Archaeological resources and rock art are under threat from natural and human-induced impacts. Human induced impacts include theft, vandalism and inappropriate development and tourism. Weathering, vegetation growth and feral animal, termite and fire damage also threaten to damage rock art and archaeological sites, all of which may be preventable impacts. Natural processes, such as tidal inundation of floodplains and storms, may threaten archaeological sites and rock art, and climate change could amplify the effects of these impacts.

5.8 Living Resource Extraction

Although the use of lead shot for hunting is banned in Kakadu National Park, this practice continues in some areas of the park. Lead poisoning through the ingestion of spent lead shot can impact on significant wildlife populations, such as magpie geese *Anseranas semipalmata* (Director of National Parks 2007). Over-harvesting of popular bush tucker items (for example, magpie geese, turtles) by not following Bininj cultural protocols or practices can impact on the populations of these species and cause social tensions.

Adequate fishing resources are also an important component of maintaining Bininj Traditional Ecological Knowledge and cultural practices. The restriction of some areas of Kakadu National Park to public fishing is important for Bininj to undertake fishing and other cultural practices in private.

6 CHANGES TO ECOLOGICAL CHARACTER

‘Ecological character’ is defined as a combination of the wetland ecosystem services/benefits, components and processes that underpin wetland systems at any given point in time. In assessing changes to ecological character for Kakadu National Park Ramsar site, as required by the National Framework (2008), the relevant timescales for the assessment of ecological character are taken to include 1980 and 1989 (when Stages I and II, respectively, were listed as Wetlands of International Importance), 1995 when Stage III wetland components were added to the Stage I area and 2010 (the time of preparation of this first ECD and the extension of the remaining Stage III area).

While there has been a considerable body of research in the Magela Creek catchment and several other areas within the site, comparatively less quantitative information exists at a whole-of-site scale. As such, the analyses below attempt to characterise whole-of-site changes to ecological character but also rely on specific investigations and information about particular areas of the site where relevant.

6.1 Ecological Character Change Methods

Based on the National Framework and similar approaches undertaken in other ECDs, a two-step approach has been employed to assess changes in ecological character for the Kakadu National Park Ramsar site as discussed in the sections below. These are:

1. based on the documentation reviewed and Ramsar Nomination Criteria listed as part of the 1998 RISs, an assessment of whether these listing Criteria continue to apply, and
2. based on the critical components, processes and services/benefits and LACs identified, whether there has been a measurable change to ecological character that is the likely result of anthropogenic activities in Kakadu National Park.

6.1.1 Assessment of Listing Criteria

Based on the analysis of the previous and current Nomination Criteria presented in Table 2-6 (refer Section 2.5), Kakadu National Park continues to meet the Nomination Criteria for which the original two sites were listed. In addition, as outlined in Section 2.5, Kakadu National Park Ramsar site is deemed to meet the three additional Ramsar Criteria.

6.1.2 Potential Changes to Ecological Character Since Listing

When considering changes in ecological character of the site, the National Framework requires the ECD to examine any changes to character that have occurred since the listing date. In order to do this, a baseline of ecological character at the time of listing must be established.

As described in Section 3.1.2, the Fox *et al.* (1977) report forms a baseline description of ecological character at the time of listing. The fact that the ‘ecosystem services’ listed by Fox *et al*. (1977) continue be supported at the present time lends support to the notion that broad scale ecological character changes of the site has not occurred.

Notwithstanding, this information forms only a qualitative basis for assessing ecological character changes since listing and more recent studies, monitoring data as well as the expert views of the

Knowledge Management Committee need also to be considered in assessing ecological character changes. Some of the key issues with regard to possible changes to ecological character are discussed below:

Exotic Flora

The prominent weed species of concern in Kakadu National Park are mimosa *Mimosa pigra*, salvinia *Salvinia*, para grass *Urochloa mutica* and olive hymenachne *Hymenachne amplexicaulis*. In general, weed management within the Park has largely contained or managed impacts of these species on wetland flora and fauna communities since listing (Director of National Parks 2007), although the success of weed management is highly variable and is dependent on resources and opportunities (Walden and Gardener 2008). Impacts from weeds are not considered to have caused a change to the ecological character of the site, with further discussion about each of the key species provided below:

Mimosa

Mimosa is a thorny shrub that was discovered in the Park in the early 1980s (around the time of listing) that grows in coastal floodplain areas of the Northern Territory, favouring seasonally or periodically inundated freshwater wetland habitats (Walden *et al.* 2004). The principal impacts from mimosa on wetland ecosystems include reduction of biodiversity and vegetation structure and alteration of hydrological regimes by encroaching into waterbodies and increasing sediment deposition. A number of studies assessing the risk of mimosa have been undertaken, the most complete and notable being Walden *et al.* (2004).

Kakadu National Park has been described as ‘an island in a sea of mimosa’, noting control has been given a high priority with approximately $7 million dollars of Australian Government funding provided to the removal of over 8000 hectares of mimosa during the early 2000s (Walden *et al.* 2004). This large scale reduction has greatly reduced the immediate risk to Kakadu National Park (Walden *et al.* 2004). Kakadu remains free from serious infestation by the systematic survey and destruction of new outbreaks, which involves four full-time staff and an annual budget of over $400 000 (Storrs *et al.* 1999).

Salvinia

Salvinia molesta is a free floating aquatic species discovered in the Kakadu National Park in 1983 and, due to its very fast reproduction rate and seasonal flooding, has now spread throughout the Magela Creek system and also can be found in the East Alligator River and Nourlangie Creek system (Storrs and Julien 1996). Significant financial and operational resources are applied to control the weed including previous trials of the use of the biological control agent *Cyrtobagous salvinae* (a weevil) (Storrs and Julien 1996). In this context, salvinia is not considered to have caused any notable ecological character changes to the site and is being adequately controlled under current management regimes (S. Winderlich pers. comm. 2009).

Para Grass

Para grass is a highly invasive pasture weed introduced as fodder for domestic livestock at Oenpelli in Arnhem Land in the 1960s. Parks Australia eradicate isolated infestations and note the South Alligator River system is at most risk from future invasion (Walden and Bayliss 2003 cited in Douglas *et al*. 2008). As per the above, the presence and distribution of para grass is not seen as change in ecological character since listing of the site.

Olive Hymenachne

In more recent times (since 2002), olive hymenachne *Hymenachne amplexicaulis* has also become a weed species of concern and management aims to control the further spread of this species (for example, refer Douglas *et al*. 2008, Walden and Gardener 2008). The presence of olive hymenachne is also a contributing factor to saline intrusion as discussed below.

Exotic Fauna

A variety of non-indigenous fauna species are known to occur within the site and include: pigs *Sus scrofa*, Asian swamp buffalo *Bubalus bubalis*, cattle *Bos* spp., horses *Equus caballus*, donkeys *E. asinus*, cats *Felis catus*, dogs *Canis lupus familiaris,* black rats *Rattus rattus*, house mice *Mus musculus*, cane toads *Rhinella marina,* flower-pot snake *Rhamphotyphlops braminus*, house gecko *Hemidactylus frenatus*, sambar deer *Cervus unicolour*, various ant species[4] and honeybees *Apis mellifera* (Press *et al.* 1995b; Director of National Parks 2007; Bradshaw 2008). These species, to varying extents, whether individually or collectively, are thought likely to add pressure to the maintenance of the sites's values for biodiversity and threatened species, although the relative impact of these on native fauna is likely to vary considerably (Gardner *et al.* 2002; Finlayson *et al.* 2006; Bradshaw *et al.* 2007). The majority of introduced taxa have been widely acknowledged as implicit in the degradation of habitat values for both native fauna biodiversity and threatened species (see Table 6-1).

Additional exotic fauna species that have a high potential to enter the Park include banteng *Bos javanicus* and crazy ants *Anoplolepis gracilipes* (Director of National Parks 2007).

Of the non-indigenous fauna recorded on the site, the greatest threats to fauna habitat values are linked to the presence of large, hard-hoofed herbivorous mammals (buffalo, horses, donkeys and pigs) and cane toads (Director of National Parks 2007; Bradshaw 2008), as discussed in further detail below:

Large Herbivores

The severe and adverse environmental impacts effected by buffalo within the site and the region has been widely reported (for example, Braithwaite *et al.* 1984; Taylor and Friend 1984; Tulloch and Cellier 1986; Skeat *et al.* 1996). As a result of a major eradication program implemented in the mid-1980s (and completed in 1997), buffalo numbers within the Alligator Rivers Region were significantly reduced (Gardner *et al.* 2002; Director of National Parks 2007). Since then, numbers within the site have increased gradually, though buffalo (and horses, donkeys and cattle) remain abundant within

[4] *Pheidole megacephala, Solenopsis geminata, Monomorium destructor, M. floricola, M. pharaonis, Paratrechina longicornis, Tapinoma melanocephalum, Tetramorium bicarinatum,* and *T. simillimum*.

neighbouring Arnhem Land and pastoral properties (Director of National Parks 2007; B. Salau pers. comm. 2009).

High buffalo numbers have in the past lead to significant environmental damage in lowland environments, and continue to represent a threat to wetland environments (such as springs, billabongs and riparian vegetation) in the stone country (Simon Ward, pers. comm. 2010). High buffalo numbers can cause severe damage to wetland environments (for example, trampling of nests, eggs and vegetation, increased stream erosion and sedimentation) and cultural resources (that is, damage to rock art, sacred sites and archaeological resources). Specifically, buffalo can damage rock art by rubbing against it, damage sacred sites through trampling and environmental degradation and destroy archaeological resources through trampling, grazing and wallowing in open artefact scatters on the flood plain (Jones 1985, Higgins 1999, D. Lindner pers. comm. 2009).

Both pigs and horses generate physical degradation of habitat, particularly around wetlands (most notably freshwater floodplains, tidal flats and monsoon forests), and are implicated in the spread of some of the most significant weed species within the site (for example, mimosa *Mimosa pigra* and olive hymenachne *Hymenachne amplexicaulis* (pigs) and mission grass *Pennisetum polystachion*, gamba grass *Andropogon gayanus* and gambia pea *Crotalaria goreensis* (horses); (Director of National Parks 2007). Pigs are regarded as common throughout the region and Kakadu National Park, and it is considered that pig abundance may have increased concomitantly with the decline in buffalo populations, although there is little quantitative data (Gardner *et al.* 2002). Pig rooting of floodplain areas, while prevalent, is reported as having a far less deleterious impact than buffalos in terms of channelisation and associated saltwater intrusion. The creation of levees and ruts from the rooting is interpreted by some to be inhibiting tidal flows (Petty *et al.* 2005). Pig rooting may be impacting on the breeding of pig-nosed turtles and populations of bush-tucker turtles and water chestnut tubers (S. Ward pers. comm. 2010).

Whilst horses are considered relatively common throughout the site, there is anecdotal evidence that both donkeys and horses are comparatively more common in the drier southern and western parts of Kakadu National Park (B. Salau pers comm. 2009).

While all of these species are actively controlled and managed, the broad scale program to eradicate buffalo from the Park in the early 1980s appears to have had the most resoundingly positive effect on the ecological character of the wetlands since listing. Research by Petty *et al.* (2005) has documented how buffalo were exacerbating the natural processes of tidal channel extension and contraction in the South Alligator floodplain through creation of swim channels. This process had been leading to extensive saltwater intrusion into the freshwater areas of Yellow Water for the decades previous. Although some billabongs in the tidal interface area of the South Alligator have been permanently lost and associated *Melaleuca* communities degraded by saltwater intrusion, it is reported that much of the 'pre-buffalo' character of the tidal interface region has been restored in the past 10 years (Petty *et al.* 2005).

Furthermore, floating grass mats (also known as sudds) within the site are thought to be recovering as a result of the reduction in buffalo numbers. Floating grass mats are a habitat found in flow channels, waterholes and billabongs of Kakadu during the wet season. They are typically comprised of a range of submerged plant species including *Leersia hexandra* and native hymenachne *Hymenachne acutigluma,* and occur along the banks of billabongs (Finlayson *et al.* 2006). Studies elsewhere in the Northern Territory in billabongs near the Finnis River south of Darwin noted the importance of these mats for a range of fauna including saltwater crocodile nesting, waterbird feeding and underwater habitat for fish and invertebrate species (Hill *et al.* 1987). In the context of historical changes to ecological character, studies in the Finnis River showed an accelerated loss of floating mats in the period from 1963 to 1978 which was principally the result of buffalo causing the detachment of mats from the bank. The floating mats present in the Kakadu National Park within billabongs and the Magela Creek are less complex or extensive compared to sites such as the Finnis River or Arafura Swamp (Cowie *et al*. 2000) and there has not been extensive study of these habitats within the Park to date. However, it is likely that this habitat (and associated ecological values) have also benefited from the removal of buffalo from the site.

Cane Toad

As mentioned in Section 5.2, a recent and notorious introduced species is the cane toad *Rhinella marina.* The preliminary risk assessment of cane toads prepared by van Dam *et al.* (2002b) outlined the potential effects of cane toads on Kakadu National Park's resources which included toxic effects on predators such as reptiles, birds and mammals, potential competition with native frogs, and cultural effects from the loss of important bush tucker species. That work assessed the susceptibility of 151 native species as potential cane toad predators and concluded that ten species were considered likely to be at risk of experiencing population level effects (northern quoll, mangrove monitor, Merten's water monitor, northern sand goanna, spotted tree monitor, northern death adder, king brown snake, dingo), with a further 12 species (or species groups) at possible risk of experiencing population level effects (leeches, snails, ornate burrowing frog, northern dwarf treefrog, desert tree frog, blue-tongued lizard, carpet python, brown tree snake, slaty-grey snake, freshwater crocodile, black bittern, blue-winged kookaburra). A notable proportion of this higher risk group comprises wetland-dependent species (three snake species, four lizard species, all frog species). Many of the 'at risk' species also represent traditional food sources. Loss of traditional food sources can lead to decreased application and transmission of traditional ecological knowledge and other activities often associated with this, including decreased used of Bininj languages and decreased application of traditional land and fire management practices.

It would appear many of these impacts foreshadowed by Van Dam *et al.* (2002b) have now been realised, with anecdotal reports of declines in the populations of a number of predatory wetland-dependent species such as freshwater crocodiles, goannas, snakes and frog fauna in Kakadu National Park and throughout the broader region (S. Winderlich pers. comm. 2009). There are no empirical estimates of the degree of impact of cane toads on native fauna populations within the site; hence firm conclusions on whether there has been a change in character can not be drawn. This represents a key information gap in the context of this ECD and broader management of Kakadu National Park.

There are presently no effective cane toad control measures. Consequently, no cane toad threat abatement plan has been developed to date.

Table 6-1 A summary of ecological and management issues associated with feral fauna species. (after Bradshaw *et al.* 2007)

Species	Densities	Habitats	Damage	Control	Issues
Pigs	Densities high close to permanent water; areas with subterranean foods; areas with dense woody or grass shelter.	Floodplains flanked by *Melaleuca* spp., woodlands, vine thickets and forests; upland palustrine areas.	Digging causing erosion/siltation. Weed dispersal. Predation on native species.	Helicopter shooting. Density reduction difficult.	General agreement on control. Adjacent uncontrolled areas are source of immigrants. Vector of Japanese encephalitis virus, Melioidosis, Brucellosis, Leptospirosis, foot and mouth disease, and Tuberculosis.
Buffalo and cattle	Historically up to 34/sq km (mostly floodplains), now <0.1/sq km at a whole of Park scale. Currently a large population in Arnhem land plateau.	All habitats, but higher in floodplains and channels, lowland forests and seasonally inundated areas.	Formerly one of the greatest threats to the region. Severe damage to waterways (erosion, saltwater intrusion). High food consumption. Altered ground cover and plant diversity.	Approximately 80 000 removed during Brucellosis and Tuberculosis Eradication Campaign (BTEC) using helicopters. 20 000 removed since BTEC. Populations increasing and moving back into region.	Buffalo farm with about 600 animals to provide meat. Important source of food and income for Aboriginals. Full eradication culturally contested Adjacent uncontrolled areas are source of immigrants. Vector of Tuberculosis and Brucellosis.
Horses and donkeys	Less abundant than pigs/buffalo. Densities unknown. Population increase up to 80 percent per year.	Drier areas near sites of previous release. High site fidelity. Can live farther from water than pigs/buffalo.	Less visible physical damage compared to pigs/buffalo. Erosion, weed dispersal, and vegetation damage. Possibly affects native herbivore densities.	Damage-density relationship unavailable and controversial. Ground and helicopter shooting controls plausible.	High controversy. Many Aboriginals view as part of landscape; horses are part of cultural heritage as many Bininj were stockmen on cattle stations that were later incorporated into Kakadu National Park. Control questioned by many external groups. Vector of Melioidosis.
Cats Also see Woinarski and Ward n.d.	Largely unknown. Abundance surveys difficult.	Throughout northern Australia, found in terrestrial and wetland (not fully aquatic) habitats.	Consume wide range of native fauna. May compete with northern quolls, snakes and goannas.	Ground-based opportunistic shooting. Difficult to trap. Poisoning is difficult and trials are currently underway.	Pets provide constant source of feral individuals. Vector of toxoplasmosis causing disease in wildlife and humans.
Dogs	Relatively lower than elsewhere in Australia. No density estimates.	Wide distribution in northern Australia.	Hybridization with dingoes. Competition with and predation on native wildlife. Impacts less than cats.	Tracking surveys, shooting, trapping, poisoning, exclusion fences.	Stray pets a source of feral individuals. Control scrutinized by external groups. Some threat of disease and parasites.
Black rats (Also see Woinarski and Ward n.d.)	Mary River Ranger station, Upper Wildman River Area, Jabiru (see Woinarski and Ward n.d.)	Common in agricultural land and human settlements. Increasing numbers of records in 'natural' bushlands (S. Ward, pers. comm. 2010).	Moderate pests of agricultural industry. Omnivorous diet. Can displace native species.	Poisoning. Making habitat less suitable. Trapping.	All stakeholders seek control, but lack of information on damage makes justification difficult. Vector of Salmonellosis and leptospirosis.
House mice	Normally low, but "plague" outbreaks can occur. Plagues unlikely in Kakadu National Park but possible after heavy rains in drier regions.	All habitat types, but higher densities in areas of higher disturbance, e.g. human settlements and clearings.	Major pests of agricultural industry. Thought to be greater threat to biodiversity than Black rats.	Baiting with strychnine, but serious side-effects for native wildlife. Possible fertility control.	All stakeholders seek control, but lack of information on damage makes justification difficult. Some threat of diseases to wildlife and humans.
Cane toads	Can exceed 2000/km^2 in favourable conditions.	Throughout northern Northern Territory.	Reduction of survival and densities of native reptiles through predation and poisoning. Competition with native wildlife. Changes in plant and animal communities.	Trapping, but time-consuming and expensive. Possibility of fertility control.	All stakeholders seek control, but effective methods are unavailable.. Possible transmission of disease to native amphibians.
Ants	Densities unknown	Wide dispersal capability, but generally localised outbreaks. Highly invasive.	Threats to invertebrate diversity. Agricultural and urban pests.	Eradication campaign in Kakadu National Park successful using poisons. Ongoing monitoring vital to identify new outbreaks.	Little community or government interest in control.
Honey	Many feral colonies	Range in Kakadu	Competition with native	Control through destruction of	Proposals to limit distribution of

Species	Densities	Habitats	Damage	Control	Issues
bees	in northern Australia. Densities unknown.	National Park unknown.	bees and birds. Reduction of "sugar bag" harvested by Aboriginal people. Changes in pollination patterns of native plant species.	hives, poisoning, insecticide strips, but less effective in fragmented landscapes.	commercial hives not implemented. Damage generally ambiguous, so control difficult to justify.

Recovery of Saltwater Crocodile Populations

The prohibition of the culling of crocodiles in the 1970s, while pre-dating listing of the Ramsar site, has led to a positive change in the character of the site through the recovery of the saltwater crocodile *Crocodylus porosus* population over the intervening period from listing to the current time (refer Section 3.3.7).

However, this increase in saltwater crocodile numbers together has had a corresponding negative impact on the populations of freshwater crocodiles *Crocodylus johnstoni*. Parks Australia has noted saltwater crocodiles to be increasingly moving into areas previously inhabited by freshwater crocodiles, with the freshwater crocodiles often killed as a result of the interaction (S. Winderlich pers. comm. 2009). The increasing presence of saltwater crocodiles further upstream within the catchments of the Park also has had a negative impact on tourism and recreational usage of the site's freshwater areas with swimming in iconic areas such as Twin Falls and Maguk are no longer permitted due to the risk of crocodile attack.

Saltwater Intrusion into Freshwater Wetland Areas

The processes and extent of saltwater intrusion into freshwater meadows of the low lying floodplains adjacent to the shores of the Van Diemen Gulf were presented by Bayliss *et al.* (1997) as 'the major coastal management problem in the Alligator Rivers Region and adjacent areas', with the problem present in both the East Alligator River-Magela Creek System and South Alligator River systems within the Park and the nearby Mary River (outside of Kakadu National Park).

Saltwater intrusion in these areas is a natural process but has been recognised as increasing over the past 50 years principally through landward extension of tidal creeks. While the presence of buffalos in these environments and motorised boat traffic (through scour) are both highlighted in the literature as having contributed to the proliferation and expansion of tidal channels in the floodplain (for example, Petty *et al.* 2005), interactions between very large magnitude meteorological and oceanographic processes are the likely primary drivers of saltwater intrusion across the northern portion of the Park. These processes include wet and dry season differences in the relative intensities of sea level, tide and flood conditions with flood channels scoured in the wet season and dominated by tidal processes and sedimentation through the natural formation of levees in the dry season (Cobb *et al.* 2007).

While the removal of buffalo has been a major improvement to floodplain health, boat traffic and olive hymenachne *Hymenachne amplexicaulis* remain contributing factors to saltwater intrusion. Boat traffic within the waterways of floodplain areas cause indirect impacts by creating small channels that scour in the wet season and channelise flows rather than allowing sheet flow across the floodplain. Olive hymenachne has readily established in these channels and has been shown to exacerbate the channelisation effect from boat traffic by reducing the width of navigational channels. The growth of native hymenachne *Hymenachne acutigluma* was previously controlled by feeding buffalo but has also flourished as a result of reduced floodplain fire management practices (Petty *et al.* 2005).

The effect of saltwater intrusion in the floodplain areas of the Park has had the effect of changing the spatial characteristics and distribution of tidal creeks and associated mangrove environments over a long time period, often at the expense of predominantly freshwater systems. This includes the loss of several freshwater billabong environments located proximal to the tidal channels and at the fresh-salt interface areas of the major river systems, noting that these features have both ecological and cultural significance in terms of bush tucker and traditional customary use.

In recognition of these impacts, the intrusion of saltwater has been studied and monitored over time and measures have been implemented by Parks Australia to control impacts. These include the afore-mentioned eradication of buffalo (the program terminated in 1997), continuing efforts by Parks Australia to control and regulate boating traffic in the river systems and in some cases through construction of temporary bunds and other capital works to deter tidal intrusion (refer BMT WBM 2010).

However, the extent to which saltwater intrusion represents an ecological character change is difficult to assess noting that saltwater intrusion into Kakadu National Park's freshwater wetlands is a continuous natural process. A key factor to be considered is whether the environmental change or the rate of change can be perceived as having an anthropogenic source. In this context, establishing what is 'natural variability' in terms of saltwater intrusion is extremely difficult and consideration of longer term trends (for example, before the listing date) have been taken into account in the setting of relevant LACs (see next section in terms of the assessment of ecological character against LACs). As will be discussed below in the context of future threats, the implications of climate change induced sea level rise must also be considered in terms of defining the 'natural' rate of change to freshwater wetland systems of Kakadu National Park and their ability to adapt to saltwater intrusion processes.

6.1.3 Assessment of Ecological Character Changes Against LACs

In order to be more definitive about changes to ecological character, the National Framework (2008) requires an assessment of whether or not any LACs set as part of the ECD have been exceeded. Drawing upon the discussions above, Table 6-2 outlines this assessment.

While there has been extensive data gathering and monitoring in the context of the impacts of uranium mining operations at Kakadu National Park for over thirty years, research about wetland environments within the Park undertaken by *eriss* and monitoring of species and habitats by Parks Australia, the broad information base for an assessment of ecological character change is limited by:

1 A largely inadequate baseline for the key parameters at the times of listing and extension in 1980/1989/1995/2010.

2 Limited continuous data sets over the intervening period to the time of ECD preparation for critical components and processes at a landscape scale.

3 Generally limited understanding of natural variability in some key parameters, noting that tropical wetland environments such as Kakadu National Park can have enormous variation within and between years or decades.

This situation is not uncommon to Ramsar sites around Australia, and is particularly understandable given the size, relative remoteness and diversity of habitats present at Kakadu National Park. With this in mind, the analysis presented in Table 6-2 should be viewed as a preliminary attempt at characterising changes in ecological character of the site since listing that can be added to and improved as part of future ECD investigations and assessments.

While the level of quantitative information and data needed to provide a more definitive assessment of ecological character change (and to set more definitive LACs sought by the National Framework) are not available, it would appear unlikely that any of the LACs presented in Table 6-2 have been meaningfully exceeded except that saltwater intrusion processes have possibly degraded freshwater billabongs and other palustrine wetlands and reduced the extent of *Melaleuca* communities.

Further information about determining change in ecological character can be found within the recently released 'National Guidance on Notifying Change in Ecological Character of Australian Ramsar Wetlands (Article 3.2)' (DEWHA 2009b). As outlined in the document, '*a breach of an LAC indicates that a component, process or benefit/service has changed beyond its natural variability and the breach of this feature, by definition, requires a remedial response*'. However, it is acknowledged by the Guidance document that there are often extreme ranges of natural variability over time, and until such time that natural variability is determined for the circumstances associated with the breach, a notification of ecological character change under the Convention will be made only where there is confidence that the change exceeds any previous condition, that is, it has not previously been experienced to that degree.

Overall, taking into account the findings of the three assessment approaches, there is no evidence to suggest that the site has experienced an ecological character change since listed.

Table 6-2 Assessment of ecological character changes against LAC

Indicator	LAC Value	LAC exceeded?	Comments
1. Reduction in mangrove extent.	Mangrove extent will not decline by greater than 25 percent over a 20 year period.	No.	Mangroves have increased between 1950-1991. There is no indication mangrove extent has declined since listing in 1980 (Stage I) and 1989 (Stage II). There are no documented studies about the impacts of higher sea levels negatively impacting on lower estuary mangroves to date.
2. *Melaleuca* forest extent.	The number of *Melaleuca* trees will not decline by greater than 50 percent of baseline values of Riley and Lowry (2002) for the year 1996 (24 704 trees) at the Magela floodplain over a 20 year period.	Unknown – but possible.	*Melaleuca* communities have been and continue to be in decline within the Magela floodplain. The lack of a consistent methodology to assess changes over time leads to difficulties in assessing long term patterns and quantification of changes since the time of listing. However, it is noted that the eradication of buffalo has largely returned the floodplain to a near pre-buffalo state. This recovery has occurred in part since listing (both Stage I -1980 and Stage II - 1989).
3. Palustrine wetland and billabongs extent.	Data deficient.	Unknown – but possible.	In particular areas of the floodplain, billabongs that are traditionally freshwater have been affected by saltwater intrusion. However, the eradication of buffalo has largely returned the floodplain to a near pre-buffalo state. This recovery has occurred in part since listing (both Stage I -1980 and Stage II - 1989).
4. Permanent waterholes and seeps in stone country.	No drying of any perennial seeps and permanent waterholes in the short and long term.	Unknown – but unlikely.	There is no evidence to suggest that anthropogenic activities have resulted in loss of perennial seeps within the site. However, there is no data to indicate flow patterns in seeps within the site.
5. Spear-tooth shark and northern river shark distribution and abundance.	The site continues to support spear-tooth shark in the long-term. Wildman and East, West and South Alligator Rivers continue to support northern river shark in the long-term.	Unknown – but unlikely.	Data deficient due to a lack of surveys. No changes to suitable habitat since listing. Increased saltwater crocodile abundance since listing may be causing deleterious impacts on shark populations as these species are a prey item.
6. Pig-nosed turtle distribution and abundance.	The average density of pig-nosed turtle will not fall below 13.5 turtles/ha.	Unknown – but unlikely.	Data deficient due to a lack of surveys. No changes to suitable habitat since listing have been recorded, nor are they likely to have occurred.
7. Flatback turtle nesting.	The average number nesting attempts measured over a one week period during the peak breeding period must not fall below 0.8 attempt/night in three successive years.	Unknown – but unlikely.	Parks Australia monitoring has shown turtle nesting occurs on Field Island and along the northern foreshore. Data collection in more recent times does not provide a baseline for assessment since listing. However, no impacts have been recorded in these habitats or evidence of a decline in nesting usage since commencement of annual monitoring.
8. Yellow chat distribution and abundance.	Flood plain habitats of the site continue to support yellow chat in the long-term.	No.	Yellow chat have recently been recorded at the site by Parks Australia, therefore this LAC is met.

Indicator	LAC Value	LAC exceeded?	Comments
9. Local endemic invertebrate species distribution and abundance.	As a minimum, sites at which each species has previously been recorded will continue to provide habitat for these species.	Unknown – but unlikely.	Data deficient due to a lack of surveys. No changes to suitable habitat since listing.
10. Waterbird abundance – resident species	Average abundance of the most common species (magpie geese, wandering whistling-duck and plumed whistling-duck) will not fall below the minimum recorded seasonal values of Morton *et al.* (1991) on more than 30 percent of sampling occasions over a 10 year period.	Unknown – but unlikely.	The absence of systematically collected data over appropriate spatial and temporal precludes an assessment of this LAC. Major changes in bird populations are not however thought to have occurred since listing.
11. Waterbird species (greater than one percent threshold).	As a minimum, sites at which each migratory shorebird has previously been recorded will continue to provide habitat for these species.	Unknown – but unlikely.	See above.
12. Waterbird abundance – migratiory species (common species) 13. Waterbird abundance – migratiory species (1% threshold species species)	Sites at which each migratiory shorebird species have been previously recorded (as per Chatto 2003) will continue to provide habitat for these species.	Unknown – but unlikely.	The absence of systematically collected data over appropriate spatial and temporal precludes an assessment of this LAC. Major changes in bird populations are not however thought to have occurred since listing.
14. Barramundi abundance in billabongs 15. Freshwater fish in billabongs	The average abundance of barramundi and other fish species will not fall below the minimum recorded values of Humphrey *et al.* (2005).	No.	Monitoring collected post listing of the Stage I area (1980) and Stage II area (1989) indicates that the populations of these fish are stable and within the bounds of natural variability.
16. Saltwater crocodile abundance.	The average abundance of saltwater crocodiles will not fall below 35 000 individuals, which represents a 50 percent reduction in the 1994 estimated population.	No.	Monitoring indicates increasing saltwater crocodile abundance within the site since listing.
17. Freshwater crocodile abundance.	The average abundance of freshwater crocodile will not fall below the minimum recorded values of Parks Australia (Figure 3-18) on more than 50 percent of sampling occasions over a 10 year period.	Unknown – but possible.	Monitoring indicates that there reduced dramatically over the last decade, possibly in response to sampling error, or actual changes in abundance due to such factors as increases in saltwater crocodile or cane toad invasion (noting that sampling is not done using systematic survey methods). There are insufficient data to assess whether there has been a change in populations since listing and whether this constitutes a change in ecological character.
18. Surface water flows – annual flows and seasonality.	A greater than 20 percent change in the long-term mean annual flow of rivers constitutes an unacceptable change.	No.	There has been limited abstraction and no works to divert water from the freshwater reaches of the major river systems with annual flows within the bounds of natural variability since listing.
19. Critical life stage processes.	• The site no longer provide adequate refuge function for important flora and fauna species and populations; OR • Critical life-cycle processes have either substantially diminished (in terms of frequency or extent of usage) or are otherwise no longer being supported (relative to natural variability).	Unknown – but unlikely.	Patterns in waterbird usage in particular known breeding, roosting and feeding sites are not identified in the literature and data review as having experienced any significant change since listing (Stage I – 1980 and Stage II – 1989). See above, re. aquatic species such as turtles and fish.
20. Fire – frequency – escarpment and lowlands.	• The area of wetland country burnt per year will not exceed maximum recorded baseline value more than twice over a 20 year period.	No	

Indicator	LAC Value	LAC exceeded?	Comments
21. Rock art, archaeological and other culturally significant sites protected	• number of sites recorded; • number of sites managed/maintained • greater than 10 percent sites damaged/lost to preventable damage • no damage to representative and high priority sites.	Unknown	Kakadu National Park's Cultural Database was established in the late 1980s and data has been gradually added until the present date, with most data collected during the 1990s. This does not provide a baseline of data prior to Kakadu National Park's Ramsar declaration and therefore it is difficult to determine whether changes have occurred since Ramsar listing. Information is not publicly available from other agencies such as the Northern Land Council and Aboriginal Areas Protection Authority to measure changes to culturally significant sites as recorded under the relevant Acts.
22. 'Living culture' is maintained	Due to the lack of quantitative data regarding 'living culture' attributes, the limits of acceptable change are unable to be defined. However a change in the ability of Bininj to own, occupy, access and use the land and resources of Kakadu National Park could result in a loss of 'living culture'. A change in the ability of Bininj to use and transmit Bininj cultural practices, knowledge, language and spirituality could also result in a loss of 'living culture'.	Unknown	Anecdotally, Bininj languages are decreasing in use and some languages (e.g. traditional Jawoyn) are only spoken by a limited number of people. Half of Kakadu National Park is land under claim and therefore Bininj land ownership remains unclear. Joint management arrangements continue to enable Bininj to occupy, access and use the land and resources. This facilitates the use and transmission of cultural practices, knowledge and spirituality.

Note: In characterising exceedance of an LAC in the Table, possible responses (based on data availability) include 'Yes', 'No', or 'Unknown'. For those LACs where an 'Unknown' response is supplied, additional justification is provided based on expert opinion using the following categories: 'Very Unlikely'; 'Unlikely'; 'Possible'; 'Likely'; 'Very Likely'.

7 INFORMATION GAPS, MONITORING AND EDUCATION

7.1 Information Gaps

The ECD preparation process promotes the identification of information or knowledge gaps about the Ramsar site. In the context of the identified critical services/benefits, components and processes in this ECD, Table 7-1 summarises the key information and knowledge gaps. Other information gaps are discussed below.

Table 7-1 Summary of information/knowledge gaps

Description of Wetland Element	Description of Information/Knowledge Gap
Critical Components	
C1. Mangroves	• Some limited data exists. An adequate baseline describing the extent of different mangrove community types across the site is needed to assess future changes to ecological character over time.
C2. *Melaleuca* forest	• Some limited data exists for Magela floodplain, but there are few data for other parts of the site. An adequate baseline describing temporal patterns in Melaleuca forest extent is required for the whole of the Park to assess future changes to ecological character over time.
C3. Palustrine wetlands and billabongs	• Some limited data exists for certain areas. An adequate baseline describing temporal patterns in the extent of palustrine wetland communities and billabongs for the whole of the Park to assess future changes to ecological character over time.
C4. Waterfalls, seeps and waterholes	• There is a need to document the location of all these features at a whole of site scale. Furthermore, there is a need to quantify flow patterns and water requirements of representative and/or important wetland in order to (i) determine baseline conditions; and (ii) determine potential sensitivity to any future changes in hydrology.
C5. Populations of migratory and resident waterbirds	• The relationship between coastal use by tourists and disturbance to shorebirds, particularly when at high tide roosts, is unknown. • There have not been regular counts for migratory and resident waterbirds since listing across the full range of wetland habitat types.
C6. Populations of freshwater fish	• Some limited data exists for particular habitats but no broad scale data sets are available across the range of wetland habitats. There is a need to develop baseline data describing patterns in fish abundance and species richness at a range of sites within representative wetland habitat types. This will enable an assessment of any future changes to ecological character.
C7. Populations of freshwater and saltwater crocodiles	• There is limited information on the current status of freshwater crocodile populations in the site, particularly in the context of impacts of cane toads. Furthermore, systematic data describing the relative abundance of crocodiles (standardised by sampling effort) in representative habitats is required to assess any future changes to ecological character.
C8. Populations of threatened sharks	• No available data on the basic life-history of these species, including dependency on estuarine and freshwater environments. • Limited available data on shark abundance and distribution within the site. • An adequate baseline is needed to identify any future changes in the distribution and abundance of these species over time and space.
C9. Yellow chat populations	• There are no systematic data describing the distribution and abundance of this species within the Park. An adequate baseline is needed to identify any future changes in the

Description of Wetland Element	Description of Information/Knowledge Gap
	distribution and abundance of this species over time and space.
C10. Pig-nosed turtle populations	• There are no systematic data describing the distribution and abundance of this species within the Park. An adequate baseline is needed to identify any future changes in the distribution and abundance of this species over time and space.
C11. Locally endemic invertebrate species	• There are no systematic data describing the distribution and abundance of this species within the Park. An adequate baseline is needed to identify any future changes in the distribution and abundance of this species over time and space.
Critical Processes	
P1. Fluvial hydrology	• With the exception of a study by Hess and Melack (2003) which had limited spatial and temporal context, there are few empirical data describing patterns in variability in estuary size and floodplain inundation area within the site. An adequate baseline is needed to identify any future changes in estuary extent over time and space.
P2. Fire regimes	• Studies have assessed fire regimes over time and impacts on vegetation communities; however, continued monitoring of fire regimes is required especially in terms of responses of new weed species to fire.
P3. Breeding and migration of waterbirds	• There is a lack of a comprehensive and integrated map of breeding areas for key waterbird species. • Refer to gaps identified in C5.
P4. Flatback turtle nesting	• Flatback turtle nesting is monitored annually by Parks Australia. There are no critical information gaps in the context of relevant LACs.
Critical Services/Benefits	
S1. Biodiversity – Support of threatened fauna	• There is a general lack of suitable surveys for the threatened species within the site, including empirical data on abundance and general life history data for species such as the river sharks. • There are currently no formal species-level monitoring programs that measure trends in abundance, or responses of these species to designated management actions of the threatened species (see review Fischer and Woinarski 2007). • Refer to critical components above for data requirements.
S2. Fisheries resource values (especially barramundi)	• There are no available data describing patterns in barramundi abundance over time or within other areas of the Ramsar site (other than the two targeted billabongs sampled by *eriss*). An adequate baseline is needed to identify any future changes in the distribution and abundance of this species over time and space.
S3. Contemporary living culture	• Many cultural elements are undocumented, including cultural practices and knowledge, some languages and much spirituality (which may be inappropriate to record).

Key information gaps also exist in terms of the impacts of key threatening processes. In particular, there is little empirical data describing the impacts of non-indigenous fauna (particularly cane toads) on native fauna populations. The relationship between the population density of non-indigenous herbivorous species and landscape/ecosystem damage is also poorly understood.

Data management and dissemination also represents a key data limitation. Information and data from survey and monitoring programs resides in a variety of forms which is widely scattered and, in many cases, difficult to access. Substantive support is required to develop a consolidated information management system for the site which will support effective biodiversity monitoring through making existing information generally accessible and providing a mechanism for storage and dissemination of 'new' data and information.

In addition to the above, it should also be recognised that *eriss* publishes a biennial assessment of key knowledge needs based on the recommendations of ARRTC (Alligator Rivers Region Technical Committee). The latest publications covering the periods 2004 to 2006 and 2007 to 2008 outline specific priorities related to existing mining operations and more broad scale monitoring needs for the Alligator Rivers Region. Some of the priorities and objectives relevant to the Ramsar values of the site that should be considered in addition to the gaps outlined above include (refer Appendix 3A and 3B in Jones and Webb 2009):

- Reassessment of current threats, including surface water transport of radionuclides that could pose human health risks to the Aboriginal population eating bush tucker.
- Review and assess ecological risks via the surface water pathways, including risks of bioaccumulation and trophic transfer.
- Investigate diffuse contamination of groundwater, particularly into irrigation areas adjacent to the Magela Creek.
- Investigate wetland filters, particularly the ability/capacity of filters to remove metals from the water column and protect downstream environments.
- Continue ecotoxicology research and assessment in relation to uranium toxicity to local native species.
- Landscape-scale analysis of impact to detect possible impacts from mining to be distinguished from those arising from other causes and/or natural variability.
- Continue to monitor and rehabilitate former mine sites of the South Alligator River valley, noting that existing monitoring of these sites currently occurs and the results reported to Parks Australia.

7.2 Monitoring Needs

In the context of the site's Ramsar status and the current ECD study, the primary monitoring needs relate to the need to assess the suitability of limits of acceptable change (versus natural variability) and to assess more definitively if changes to ecological character have occurred or are being approached. Principally, this monitoring should relate to:

- Broad-scale observation/monitoring of wetland habitat extent (noting that a logical precursor to this would be to establish a better correlation between existing wetland mapping and the Ramsar wetland type classification system).
- Habitat condition monitoring (principally in the form of monitoring underlying wetland ecosystem processes such as water quality and hydrological process or surrogate biological indicators).
- Formal species-level monitoring programs for threatened species, specifically measuring trends in abundance and responses of these species to designated management actions for them.
- More regular counts of breeding, roosting and feeding waterbirds with a particular emphasis on those species that meet the one percent population threshold and in key life-cycle locations.
- Continued and more intensive survey and monitoring of fish and invertebrate species that underpin the critical services of the site including key nursery area and spawning sites.

- A monitoring program for non-indigenous flora and fauna, providing data on habitat, densities and damage. Data needs to be analysed within the appropriate quantitative frameworks to provide robust appraisals of the threats of non-indigenous species (risk analysis) and the options for control (cost–benefit analyses) (Finlayson *et al.* 2006; Bradshaw *et al.* 2007).

- Monitor the number, nature and condition of archaeological materials, sites and rock art sites associated with wetland environments and habitats that contribute to historical cultural heritage values of the sites for Bininj.

7.3 Communication, Education, Participation and Awareness

The Ramsar Convention recognises that developing communication, education, participation and awareness (CEPA) messages is a powerful tool for the conservation and wise use of wetlands. As such, the Convention has a CEPA Program that was adopted by Resolution X.8 in 2008 (following previous Resolutions in 1999 and 2002). The guidelines of the CEPA Program encourage Contracting Parties to a number of activities that promote Wetland CEPA.

A comprehensive CEPA program for an individual Ramsar site is beyond the scope of an ECD, but key communication messages and CEPA actions, such as a community education program, can be used as a component of a management plan.

A combined set of CEPA messages relevant to the ECD can be used to communicate the importance of the Kakadu National Parks Ramsar site, why they were listed, the ecological character of the site, threats to the site and future actions required. These key messages also serve as a summary of the key findings and conclusions of the ECD study and are as follows:

- Kakadu National Park is listed as a Wetland of International Importance under the Ramsar Convention and meets all nine Nomination Criteria.

- The Kakadu National Park Ramsar site was historically two separate Ramsar sites within Kakadu National Park. These were Kakadu National Park (Stage I including wetland components of Stage III) and Kakadu National Park (Stage II). Kakadu National Park Stage I encompassed the East Alligator River, Stone County and inland areas of the Park, and the Stage II site which is centred on the floodplain wetlands associated with the Wildman, West Alligator and South Alligator River systems. In April 2010, the two Ramsar sites were merged together to form a single Ramsar site, called Kakadu National Park. In addition, the site was extended by approximately 600 000 hectares to include all remaining areas of Stage III. The merger and extension bought the Ramsar boundary in line with the existing boundary of the national park.
- Through its unique and outstanding cultural landscape, the world’s oldest ‘living culture’, extraordinary rock art, archaeological resources and Bininj environmental management, Kakadu National Park provides a unique example of wise use of wetlands through the application of traditional Bininj practices. This provides excellent opportunities to showcase wise wetland management through a cultural landscape and to empower local communities.
- Limits of acceptable change for these wetland services, components and processes have been set by the ECD that can be used in future planning and management of the Park. In particular,

the ECD outlines information gaps and monitoring needs for assessing whether the ecological character of the site is being maintained over time.

- Based on a review of information and data at the time of the site's listing in 1980 and 1989 in combination with the extensions in 1995 and 2010, critical components, processes and services identified as being present at the time of listing continue to be provided by the site at the time of preparation of this ECD in 2010. This includes the site continuing to support substantial waterbird, saltwater crocodile, turtle and fish populations during different life history stages, the presence of a range of wetland species of conservation significance, and cultural and provisioning services that are significant to both indigenous and non-indigenous wetland users.
- While it is considered that there has not been a change in ecological character since listing, there are particular wetland elements that appear to have declined in abundance since the time of listing. In particular, saltwater intrusion into freshwater wetland areas has resulted in the loss of freshwater billabongs and associated *Melaleuca* communities that have high natural and cultural values. Anecdotal evidence suggests that the abundance of some wetland-dependant fauna, such as freshwater crocodiles *Crocodylus johnstoni*, may have declined since listing, possibly in response to cane toad invasion. Further research is required to quantify changes and to possible implications with respect to maintaining the ecological character of the site.
- A number of weeds have proliferated within the Park since listing (mimosa, salvinia, para grass, olive hymenachne), but as a result of active management and control, it is a conclusion of the study that the ecological character of the site has not been significantly changed or degraded.
- Positive changes to ecological character have also occurred over the intervening decades since listing of the site, principally through the eradication of buffalo from the Park's floodplain wetlands and the return of these environments to somewhat of a 'pre-buffalo' state.
- In terms of future threats to ecological character, the site continues to be threatened by weeds and other exotic flora, exotic fauna, impacts from increasing visitors and recreational activities, mining activities and future threats such as climate change which is likely to exacerbate saltwater intrusion impacts already observed.
- Given the current and future threats, it is imperative that ecological understanding of the site continues to be obtained and developed and wherever practicable, broad-scale monitoring of possible changes to ecological character needs to be pursued.

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9 GLOSSARY

Acceptable change, means the variation that is considered acceptable in a particular measure or feature of the ecological character of the wetland. Acceptable variation is that variation that will sustain the service, component or process to which it refers.

Aeolian sedimentation, means deposition of material transported by wind.

Aquatic/marine fauna, in the context of this report relates to fauna species that spend all or the majority of their life cycle in or underwater. As such this grouping primarily relates to fish, marine reptiles, aquatic mammals such as dugong and cetaceans, and aquatic/marine invertebrates.

Bininj (pronounced ‘binn-ing’), is a Kunwinjku and Gundjeihmi word that refers to traditional owners of Aboriginal land and traditional owners of other land in Kakadu National Park, and other Aboriginals entitled to enter upon or use or occupy the Park in accordance with Aboriginal tradition governing the rights of that Aboriginal or group of Aboriginals with respect to the Park (Director of National Parks 2007).

Catadromous, refers to organisms that live in freshwater but migrate to marine waters to breed.

Congener, means species within the same genus.

Ecological character, defined under Resolution IX.1 Annex A: 2005 of the Ramsar Convention as, the combination of the ecosystem components, processes and benefits/services that characterise the wetland at a given point in time.

Expert opinion, in the context of interpreting LACs relates to competent, experienced, independent individuals that have formal qualifications or otherwise expert knowledge in the disciplines of wetland ecology, hydrology or associated fields.

IMCRA bioregion, refers to the Interim Marine and Coastal Regionalisation for Australia (Mesoscale) to the 200 metre isobath and derived from biological and physical data, (for example, coastal geomorphology, tidal attributes, oceanography, bathymetry and intertidal invertebrates).

Mangal, means mangrove habitat consisting of mangrove trees and shrubs and their associated faunal communities.

National Framework document, refers to the National Framework and Guidance for Describing the Ecological Character of Australia’s Ramsar Wetlands (DEWHA 2008) and its successive documents as endorsed by the Natural Resource Management (NRM) Ministerial Council.

Potadromous, refers to organisms that complete their entire lifecycle in freshwaters.

Ramsar Criteria, refers to the nine Criteria for the listing of a site as internationally significant under the provisions of the Ramsar Convention. Also referred throughout the report as the Nomination Criteria for the site.

Sedimentation, means the process of deposition of sediment of any size. This is often colloquially referred to as siltation, but this term implies that only silt-sized material is deposited.

Shorebirds, as used in this report, refers to both resident and migratory species which are ecologically dependent upon wetlands from the following families: Scolopacidae; Burhinidae; Haematopodidae; Recurvirostridae; Charadriidae; and Glareolidae. Shorebirds form a sub-set of the waterbird grouping.

Values, means the perceived benefits to society, either direct or indirect that result from wetland functions. These values include human welfare, environmental quality and wildlife support.

Waterbirds, refers to those species which are ecologically dependent upon wetlands from the following families: Anseranatidae, Anatidae, Podicipedidae, Anhingidae, Phalacrocoracidae, Pelecanidae, Ardeidae, Threskiornithidae, Ciconiidae, Gruidae, Rallidae, Scolopacidae, Rostratulidae, Jacanidae, Burhinidae, Haematopodidae, Recurvirostridae, Charadriidae, Glareolidae, Laridae and Sternidae (after Kingsford and Norman 2002; Wetlands International 2006). Only those species of gulls (Laridae) and terns (Sternidae) which make extensive use of shallow, inshore waters or inland wetlands are included. Whilst at least some other species of other families traditionally regarded as “seabirds” (that is, Spheniscidae, Phaethontidae, Sulidae, Fregatidae, Stercorariidae and Alcidae) also make use of shallow, inshore waters (and thus could be therefore be considered as waterbirds), these have not been included in the waterbird group (following precedent within Wetlands 2006). Shorebirds form a sub-set of the waterbird grouping.

Wetlands, is used in this report in the context of the definition under the Ramsar Convention which includes, areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine water the depth of which at low tide does not exceed six metres.

Wetland-dependent terrestrial fauna, in the context of this report relates to fauna species that occur within or otherwise are dependent on wetland habitats but do not spend the majority of their life cycle underwater (for example, non-aquatic species). As such this grouping primarily relates to birds, amphibians such as frogs, non-aquatic mammals such as water mouse, non-aquatic reptiles and terrestrial invertebrates.

Wetland flora, in the context of this report relates to flora species that are characterised as wetland or wetland-dependent species or populations.

Wetland ecosystem components, as defined in the ECD National Framework document, are the physical, chemical and biological parts or features of a wetland.

Wetland ecosystem processes, as defined in the National Framework document, are the dynamic forces within the ecosystem between organisms, populations and the non-living environment. Interactions can be physical, chemical or biological.

Wetland ecosystem benefits or services (includes the term ecosystem services), as defined in the National Framework document, are the benefits that people receive from wetland ecosystems. In general, benefits and services are based on or underpinned by wetland components and processes and can be direct (for example, food for humans or livestock) or indirect (for example, wetland provides habitat for biota which contribute to biodiversity).

APPENDIX A: PROJECT COMMITTEES

The ECD and RIS update for the Kakadu National Park Ramsar site was prepared over a 12 month period. The commission involved the formation of a Steering Committee to oversee development and review of the draft and final documents and a Knowledge Management Committee to provide expert input to the consultant project team about the site's ecological character.

A1 Steering Committee

A Steering Committee was created as part of the project and was chaired by the Department of Sustainability, Environment, Water, Population and Communities.

Steering Committee meetings undertaken during the project prior to submission of the final draft document included:

Date	Type/Location	Meeting Purpose
23 July 2009	Teleconference	Provide overview of the scope of the project including the National Framework; discuss the draft critical services/benefits, component and processes.
January 2010	Face to Face	Presentation of the draft ECD for comment including overview of the structure, content and key findings of the document.
June 2010	Teleconference	Discussion on comments received on the Draft Final ECD and how these were to be addressed.

A2 Knowledge Management Committee

A Knowledge Management Committee (KMC) workshop was held on 6 August 2009 in Darwin. The agenda for the day consisted of a general presentation to provide an overview of the site and the methods to be used in preparing the ecological character description (based on the National Framework and Guidance).

The main focus of the day was a series of workshop style exercises that aimed to elicit from the KMC representatives:

- Advice about the critical services/benefits that flow from the Nomination Criteria for the site including the noteworthy threatened flora and fauna species, important habitat features and services (for example, breeding, roosting, feeding) and similar matters.
- Advice about the critical services/benefits that are derived from human use or association with the site such as indigenous significance, fishing, recreational, tourism and similar activities (in a workshop setting).

- Advice about the wetland processes (for example, hydrodynamics, water quality, etc) that underpin the wetland components in each of the conceptual model areas. This was important to identify the most 'critical' processes that underlie wetland values in the study area and form the basis for future analysis of natural variability and limits of acceptable change.

- Advice about any perceived changes to ecological character of the site since listing and identification of previous or current threats to ecological character of the site (using a whiteboard exercise).

Notes on the key outcomes and comments made during the workshops are summarised in a progress report submitted to DSEWPAC during executation of the project.

A3 Stakeholder Consultation

A3.1 Background

Following on from the KMC workshop, a consultation meeting was held at Jabiru with key stakeholders and traditional owners. The consultation program had the following objectives:

- To engage with and consult key stakeholders and traditional owners in appropriate forums.
- To empower key stakeholders and traditional owners to provide input into the study and for BMT WBM to gather information about key aspects of ecological character from the key stakeholders and traditional owners.
- To engender a shared understanding and acceptance of key management agencies of the critical natural and cultural services/benefits of the wetlands and the underpinning critical wetland processes and components which characterise the Ramsar values of Kakadu National Park

The specific aims of the consultation meeting were to:

- provide information on the study and the process to be followed for development of an ECD
- present the outcomes of the KMC workshop
- provide a forum for feedback on the outcomes of the KMC workshop including identification of gaps and/or additional ecosystem services, components and processes, threats and ecological character changes that have occurred since listing, and
- provide information on 'what's next' for this study.

One half day workshop was held in a central location (Kakadu National Park Headquarters) on the 26th August 2009. While the consultation meeting provided the main forum for consultation, it was recognised that some stakeholders were not able to attend the meeting. A summary sheet was produced which provided background information about the study, the ECD and the RIS, and summarised the outcomes of the KMC workshop and the consultation meeting in Jabiru. Contact details (telephone, post and email) for study team representatives were also provided so that those unable to participate in the consultation meeting could provide information/feedback to the study team.

The workshop was composed of a number of slide show presentations and informal group sessions which discussed various topics. Feedback was sought from participants throughout the workshop. During the workshop, maps were used to illustrate spatial issues and notes were taken to record information provided by participants.

A3.2 Outcomes of Consultation

Thirty-six people participated in the workshop, including nineteen Aboriginal people and seventeen non-Aboriginal people. The workshop was interactive and a substantial amount of information was shared by participants with the study team. The study team was also able to share information with participants on Ramsar in general and more specific topics. Topics covered included:

- What is Ramsar?
- Study team findings to date
- Knowledge Management Committee meeting outcomes
- Habitat types of Kakadu National Park
- Nomination Criteria for Kakadu National Park
- Critical services/benefits
- Cultural characteristics
- Changes to critical services/benefits and cultural characteristics
- Threats to tourism, recreation and cultural values

Notes from the workshop were collated and provided to the DSEWPAC as part of a progress report and used to develop the Kakadu National Park ECD and RIS Update documents.

A3.3 Conclusions

A large number of people attended the workshop and actively participated in listening to presentations, providing feedback and undertaking group discussion. The information provided will be relevant and useful in preparing the Kakadu National Park ECD and RIS update documents. The study team were also able to inform Kakadu National Park stakeholders about the application of the Ramsar Convention to Kakadu National Park and to learn from participants how this may be most appropriately used by those who manage the Kakadu National Park Ramsar site.

The Kakadu National Park-based workshop fulfilled the objectives of the Kakadu National Park ECD and RIS Update Consultation Strategy by providing information to key stakeholders and Traditional Owners in Kakadu National Park and providing them with an opportunity to contribute to the study in an appropriate forum.

APPENDIX B: DETAILED METHODS

B1 Selection of Critical Services, Components and Processes

B1.1Methods – Information Collation and Review Stage

The first step in ECD preparation outlined in the National Framework document is to identify the wetland services/benefits, wetland components and wetland processes present in the Ramsar site. These key terms are defined in Section 1 of the Report and the Glossary (refer Section 9). This was initiated by undertaking a process of information collation and literature review.

As part of the information collation phase, literature and existing data relevant to the study area (site boundary and surrounds) were collated and reviewed. Relevant existing information was sourced from the following:

- published scientific papers
- database records (EPBC Protected Matters Search Tool, Parks Australia databases, etc.)
- quantitative data (bird count data, etc.)
- mapping products supplied by Parks Australia (vegetation and wetland mapping)
- management plans, strategies and other policy documents, and
- grey literature from internet searches and other sources of data.

Each article of information was collated to a cursory level sufficient to determine its relevance to the study. The collected information was then reviewed to prioritise and identify information of direct relevance to the ECD.

As part of the information collation phase, key information sources to be used in the study were presented to the project Steering Committee and gaps were identified on the basis of these reviews. In some cases, additional information was supplied directly by Steering Committee representatives.

B1.2Methods – Selection of Critical Components, Process and Services/Benefits

Following the information collation and review phase, the study team collectively identified the relevant components, processes and services/benefits of the wetland. This process was based primarily upon a review of the literature and professional opinion. Using the categories and list of components, processes and services/benefits from the National Framework as a guide, it was apparent that the Kakadu National Park Ramsar site provides a broad spectrum of components, processes and ecosystem services/benefits. This included: provisioning services such as provision of traditional foods, regulatory services such as erosion protection and water quality maintenance, cultural services such as recreational fishing and hunting, tourism, cultural heritage, education and research and supporting ecosystem services such as biodiversity and the presence of endangered and vulnerable species.

Likewise, given the scope, areal extent and diversity of wetland environments present within the Kakadu National Park Ramsar site, all wetland components and processes from the National Framework were seen as occurring within the site, including a broad range of hydrological, climatic, geomorphologic, physico-chemical, biogeochemical and biological processes. It was noted that while each of these processes play a part in underpinning normal wetland functioning, some of these factors such as coastal hydrodynamics and climate also operate at both regional scales and local scales.

As outlined in Section 2, a range of wetland habitat types are known to be present within the site boundaries including those designated within the coastal/marine, inland and man-made wetland categories under the Ramsar classification scheme. Within these systems, a rich diversity of wildlife exists from all the major groups of organisms (from planktonic organisms to vertebrates) which make up the components of the wetland.

With the full range of ecosystem components, processes and services/benefits represented, there was a need to identify the most important or critical in the context of the Ramsar site. Following the method within the National Framework, the assignment of a given wetland process, component or service/benefit as critical was determined with reference to the following criteria:

- the component, process or service/benefit is an important determinant of the uniqueness of the site, or is widely accepted as representing a particularly outstanding example of an environmental value supported by the site
- the component, process or service/benefit is important for supporting one or more of the Ramsar Nomination Criteria under which the site was listed, and
- a change to the component, process or service/benefit would result in a fundamental change in ecological character of the site.

To supplement the criteria from the National Framework, additional consideration was given to suggestions or recommendations regarding critical services, components or processes by the Steering Committee and Knowledge Management Committee (particularly where such information was also documented in scientific literature). Accordingly, a set of draft critical services/benefits were presented to the Knowledge Management Committee at its meeting in August 2009 and minor revisions made as part of this process.

In addition to critical components, processes and services/benefits, a range of other elements were identified as being important to the maintenance of the morphological, physio-chemical and biological processes. These ‘supporting’ components, processes and services/benefits, while important to wetland functioning, were in isolation were not considered to directly address the criteria listed above. For example, a change in water quality (a supporting process) would not itself be considered to result in a change to ecological character. While changes to a supporting element may result in an ecological response, it is considered that such changes would be adequately captured through assessment of LACs for critical components, processes or services/benefits.

Justification for inclusion of critical and supporting components, processes or services/benefits is provided in the body of this report.

In selecting key species/groups that underpin critical components, processes and services/benefits, the following methods were considered:

B1.3.1 Flora Species

In nominating particular wetland flora species or communities for consideration under the critical components, the following considerations were applied:

a. species should generally occur in aquatic environments (for example, macrophytes) or are otherwise considered to be wetland-associated species or communities, and

b. species or communities should be listed as threatened (i.e. vulnerable or endangered) at the National (threatened under EPBC Act) and/or International (IUCN) level or are considered to be particularly noteworthy or critical from a regional biodiversity perspective (refer to Nomination Criterion 3). This includes species or communities that are perceived by the authors to be iconic to the site, or are designated as threatened under Northern Territory legislation (endangered or vulnerable at a State/Territory scale).

B1.3.2 Fauna Species

In nominating particular fauna species/groups for consideration under the critical components, the following considerations were applied:

1. Species should generally occur in aquatic or marine environments or are otherwise considered to be wetland-dependent terrestrial species (refer Glossary in Section 9 for definitions of these terms and Appendix C for list of species).

2. Species should be either:

   a. Designated as threatened (for example, endangered or vulnerable) at a national scale (under the EPBC Act) or international scale (under IUCN Red List), or

   b. Particularly noteworthy or critical from a regional biodiversity perspective (refer to Nomination Criteria 3 or 7). This includes species that are perceived by the authors to be iconic to the site, or are designated as threatened under Northern Territory legislation (endangered or vulnerable at a State/Territory scale).

3. Given the boundaries of the Ramsar site are largely confined to near-shore areas or internal waters, emphasis has been placed on inclusion of those species that use the site as core habitat, have significant population numbers and spend a large proportion of their life cycle within the site boundaries. This excludes vagrant species of conservation significance such as whales, sharks and migratory seabirds that may only occur in the Ramsar site infrequently but for which species records within the site exist.

B1.3.3 Populations

Populations of wetland biota that form the critical components are more generic groupings that recognise the abundance and diversity of animals that utilise the various wetland habitats of the site. This includes for example, amphibians, reptiles, mammals, fish, birds and aquatic invertebrates.

B2 Derivation of Limits of Acceptable Change

B2.1. General

Limits of Acceptable Change were derived using a staged approach as follows:

- determine values of the site. These represent the critical components (Section 3.3) and services/benefits (Section 3.7)
- identify critical processes underpinning site values. These are the critical processes, and are outlined in Section 3.5 of the report
- describe patterns in natural variability in critical components, processes and services/benefits indicators. Variability in indicators is described in Sections 3.3, 3.5 and 3.7 of the report
- define the relative magnitude of acceptable change. The relative magnitude of acceptable change was determined on the basis of (i) an assessment of criticality of the site to the maintenance of species populations or habitats, based on known or likely patterns in geographic distribution, abundance and criticality of the site to maintaining the survival of a species; (ii) patterns (short-term and long-term) in natural variability; and (iii) a qualitative assessment of the vulnerability of changes outside bounds of natural variability, and
- derive specific limits of acceptable change. The broad relative magnitude of acceptable change definitions was used to describe specific limits of acceptable change.

B2.2 Defining Relative Magnitude of Acceptability

The specific values of the site was determined on the basis of (i) known or likely patterns in the distribution and abundance of species and habitats that comprise the critical services/ benefits and components of the site, and (ii) expert opinion and or empirical data describing the criticality of the site to maintaining the survival of a species. Three levels of criticality were derived based on these factors (Least, Moderate and Highest Concern), as described in Table B-1 below.

Table B-1 Categories describing importance of the site to maintaining habitats and species that underpin the critical services/benefits and components

Distribution and criticality to populations	Abundant	Uncommon
Widespread globally and nationally, life-history functions supported in many areas elsewhere (species).	1a	2b
High diversity feature (habitat and community descriptor).	1b	2c
Habitat specialist with disjunct and very limited number of populations globally and nationally (species).	3a	3d
May be widespread nationally or regionally but is a critical breeding, staging or feeding site that is critical to survival of population (habitat and species).	3b	3e
Limited to bioregion but found in numerous basins, and is not known to be critical to survival of a species (habitat and species).	2a	3f
Limited to bioregion, found in a small number of basins and has limited distribution in the site (species).	3c	3g

Where least concern = 1 (green), of concern = 2 (yellow), most concern = 3 (orange)

The relative magnitude of acceptable change was then determined based on:

- The categories describing site values/importance described in Table B-1 above.
- Whether species/habitats that underpin the critical components or services/benefits are known or likely to be highly sensitive/intolerant to changes in environmental conditions.
- Known/likely patterns in natural temporal variability of indicators in the short-term (based on inter-annual cycles or episodic disturbance) and long-term (based on processes operating over time scales measured in decades). Three broad categories were adopted to describe variability at the two temporal scales (inter-annual and decadal):
  - Highly variable: greater than 60 percent change
  - Medium variable: ten to 60 percent change, and
  - Stable: less than ten percent change.
- A high level qualitative assessment of the consequences associated with changes in parameters outside natural variability was undertaken. Five consequence categories were derived, and are based in part on general risk categories developed by the SCFA – FRDC Project Team (2001) for the Risk Assessment Process for Wild Capture Fisheries (Version 3.2) (refer Table B-2).
- Consideration of patterns in natural variability, site values/importance and the consequence ratings for assessing sensitivity to change were used to derive three relative magnitude of acceptable change categories: (i) no change; (ii) small change; (iii) moderate to large change. These are shown in Table B-3.

Table B-2 Defining impact magnitude

Category	Habitat affected/modified	Key species	Ecosystem functioning
Major	>60% habitat	Mortality likely local extinction.	Total ecosystem collapse.
High	30-60%	Mortality may affect recruitment and capacity to increase.	Measurable impact to functions, and some functions are missing/ declining/ increasing outside historical range and/or facilitate new species to appear.
Moderate	5-30%	Mortality within some spp. Levels of impact at the maximum acceptable level.	Measurable changes to ecosystem components but no loss of functions (no loss of components).
Minor	<5%	Affected but no impact on local population status (e.g. stress or behavioural change to individuals).	Keystone species not affected, minor changes in relative abundance.
Negligible	<1%	No impact.	Possible changes, but inside natural variation.

Table B-3 Relative magnitude of acceptable change categories for LAC indicators

Impact Significance	Level 3 species or habitat	Level 2 species or its habitat		Level 1 species or its habitat			
		Short-term, localised	Long-term or multiple areas	Short-term, localised	Short-term, multiple areas	Long-term, localised	Long-term, multiple areas
Major	No change	No change	No change	No change	No change	No change	No change
High	No change	No change	No change	Moderate change	No change	No change	No change
Moderate	No change	Small change	No change	Moderate change	Small change	Small change	No change
Minor	No change	Moderate change	Small change	Moderate change	Moderate change	Moderate change	Small change

APPENDIX C: FAUNA SPECIES LISTS

Site Mammal List

Latin Name	Common Name
TACHYGLOSSIDAE	**Echidnas**
Tachyglossus aculeatus	short-beaked echidna
DASYURIDAE	**Dasyurids**
Antechinus bellus	fawn antechinus
Dasyurus hallucatus	northern quoll
Pseudantechinus bilarni	sandstone pseudantechinus
Phascogale pirata	northern brush-tailed phascogale
Planigale ingrami	long-tailed planigale
Planigale maculata	common planigale
Sminthopsis virginiae	red-cheeked dunnart
PERAMELIDAE	**Bandicoots and bilbies**
Isoodon macrourus	northern brown bandicoot
PETAURIDAE	**Striped possum and wrist-winged gliders**
Petaurus breviceps	sugar glider
PSEUDOCHEIRIDAE	**Ringtail possums and greater glider**
Pseudocheirus dahli	rock ringtail possum
PHALANGERIDAE	**Brushtail possums and cuscuses**
Trichosurus vulpecula arnhemensis	northern brushtail possum
MACROPODIDAE	**Wallabies, kangaroos, tree-kangaroos**
Lagorchestes conspicillatus	spectacled hare-wallaby
Macropus agilis	agile wallaby
Macropus antilopinus	antilopine wallaroo
Macropus bernardus	black wallaroo
Macropus robustus	common wallaroo
Onychogalea unguifera	northern nailtail wallaby
Petrogale brachyotis	short-eared rock-wallaby
Peradorcas concinna	narbarlek
PTEROPODIDAE	**Flying-foxes, fruit-bats, blossum-bats**
Pteropus alecto	black flying-fox
Pteropus scapulatus	little red flying-fox
Macroglossus minimus	northern blossom bat
MEGADERMATIDAE	**False vampires**
Macroderma gigas	ghost bat
HIPPOSIDERIDAE	**Leafnosed-bats**
Hipposideros ater	dusky leafnosed-bat
Hipposideros diadema	diadem leafnosed-bat
Hipposideros stenotis	northern leafnosed-bat
Rhinonicteris aurantius	orange leafnosed-bat
EMBALLONURIDAE	**Sheathtail-bats**
Saccolaimus flaviventris	yellow-bellied sheathtail-bat
Saccolaimus saccolaimus	bare-rumped sheathtail-bat
Taphozous georgianus	common sheathtail-bat
Taphozous kapalgensis	white-striped sheathtail-bat
MOLOSSIDAE	**Freetail-bats**
Chaerephon jobensis	northern freetail-bat

Mormopterus beccarii	Beccari's freetail-bat
Mormopterus loriae	little northern freetail-bat
VESPERTILIONIDAE	**Vespertilionid bats**
Chalinolobus gouldii	Gould's wattled bat
Chalinolobus nigrogriseus	hoary wattled bat
Miniopterus schreibersii	common bentwing-bat
Myotis moluccarum	northern myotis
Nyctophilus arnhemensis	Arnhem long-eared bat
Nyctophilus daedalus	northern long-eared bat
Nyctophilus geoffroyi	lesser long-eared bat
Nyctophilus walkeri	pygmy long-eared bat
Pipistrellus westralis	mangrove pipistrelle
Pipistrellus adamsi	forest pipistrelle
Scotorepens greyii	little broad-nosed bat
Scotorepens sanborni	northern broad-nosed bat
Vespadelus caurinus	northern cave bat
MURIDAE	**Murids**
Conilurus penicillatus	brush-tailed rabbit-rat
Hydromys chrysogaster	water-rat
Melomys burtoni	grassland melomys
Mesembriomys gouldii	black-footed tree-rat
Mesembriomys macrurus	golden-backed tree-rat
Pseudomys delicatulus	delicate mouse
Pseudomys nanus	western chestnut mouse
Rattus colletti	dusky rat
Rattus tunneyi	pale field-rat
Xeromys myoides	water mouse
Zyzomys argurus	common rock-rat
Zyzomys woodwardi	large rock-rat
Zyzomys maini	

Site Reptile List

Latin Name	Common Name
CROCODYLIDAE	**Crocodiles**
Crocodylus johnstoni	freshwater crocodile
Crocodylus porosus	saltwater crocodile
CHELIDAE	**Chelid turtles**
Carrettochelys insculpta	pig-nosed turtle
Chelodina burrungandjii	
Chelodina rugosa	northern long-necked turtle
Elseya dentata	northern snapping turtle
Elseya jukesi	
Elseya latisternum	saw-shelled turtle
Emydura victoriae	northern red-faced turtle
GEKKONIDAE	**Geckos**
Diplodactylus ciliaris	spiny-tailed gecko
Lucasium occultum	
Lucasium stenodactylum	sand-plain gecko
Gehyra australis	northern dtella
Gehyra nana	
Gehyra pamela	
Heteronotia binoei	Bynoe's gecko
Nephrurus asper	prickly knob-tailed gecko

Latin Name	Common Name
Oedura gemmata	
Oedura marmorata	marbled velvet gecko
Oedura rhombifer	zigzag gecko
Pseudothecadactylus lindneri	Gian cave gecko
PYGOPODIDAE	**Legless lizards**
Delma borea	
Delma tincta	
Lialis burtonis	Burton's snake-lizard
Pygopus nigriceps	hooded scaly-foot
AGAMIDAE	**Dragons**
Amphibolurus gilberti	Gilbert's dragon
Chelosania brunnea	chameleon dragon
Chlamydosaurus kingii	frill-neck lizard
Ctenophorus caudicinctus	ring-tailed dragon
Diporiphora albilabris	
Diporiphora bilineata	two-lined dragon
Diporiphora magna	
Lophognathus temporalis	
VARANIDAE	**Goannas**
Varanus acanthurus	spiny-tailed monitor
Varanus glepopalma	twilight monitor
Varanus gouldii	Gould's goanna
Varanus indicus	mangrove monitor
Varanus mertensi	Merten's water monitor
Varanus mitchelli	Mitchell's water monitor
Varanus panoptes	yellow-spotted monitor
Varanus primordius	northern Ridge-tailed monitor
Varanus scalaris	spotted Tree monitor
Varanus tristis	black-headed monitor
SCINCIDAE	**Skinks**
Carlia amax	
Carlia gracilis	
Carlia tricantha	
Cryptoblepharus carnabyi	
Cryptoblepharus megastictus	
Cryptoblepharus plagiocephalus	
Ctenotus arnhemsis	
Ctenotus coggeri	
Ctenotus essingtoni	
Ctenotus gagudju	
Ctenotus inornatus	
Ctenotus kurnbudj	
Ctenotus pantherinus	
Ctenotus robustus	
Ctenotus saxatilis	
Ctenotus storri	
Ctenotus vertebralis	
Egernia obiri	
Glaphyromorphus douglasi	
Glaphyromorphus isolepis	
Lerista karlschmidti	
Menetia alanae	
Menetia concinna	

Latin Name	Common Name
Menetia greyii	
Menetia maini	
Morethia ruficauda	
Morethia storri	
Notoscincus ornatus	
Proablepharus tenuis	
Tiliqua multifasciata	centralian blue-tongued lizard
Tiliqua scincoides	common blue-tongued lizard
TYPHLOPIDAE	**Blind snakes**
Ramphotyphlop guentheri	
Ramphotyphlops ligatus	
Ramphotyphlop tovelli	
Ramphotyphlop unguirostris	
BOIDAE	**Pythons**
Anterasia childreni	children's python
Aspidites melanocephalus	black-headed python
Liasis fuscus	water python
Liasis olivaceus	olive python
Morelia spilota	carpet python
Morelia oenpelliensis	Oenpelli rock python
ACROCHORDIDAE	**File snakes**
Acrochordus arafurae	Arafuran file snake
Acrochordus granulatus	little file snake
COLUBRIDAE	**Colubrid snakes**
Boiga irregularis	brown tree snake
Ceberus rynchops	bockadam
Dendrelaphis punctulata	common tree snake
Enhydris polyepis	Macleay's water snake
Fordonia leucobalia	white-bellied mangrove snake
Myron richardsonii	Richardson's mangrove snake
Stegonotus cucullatus	slaty-grey snake
Tropidonophis mairii	Keelback
ELAPIDAE	**Elapid snakes**
Acanthophis praelongus	northern death adder
Brachyurophis roperi	northern sovel-nosed snake
Demansia atra	black whip snake
Demansia olivacea	marble-headed whipsnake
Demansia papuensis	greater black whipsnake
Furina ornata	orange-naped snake
Oxyuranus scutellatus	taipan
Pseudechis australis	king brown snake
Pseudonaja nuchalis	western brown snake
Rhinoplocephalus pallidceps	northern small-eyed snake
Suta punctata	little spotted snake
Vermicella multifasciata	northern bandy-bandy

Site Frog List

Latin Name	Common Name
HYLIDAE	**Tree frogs**
Cyclorana australis	giant frog
Cyclorana longipes	long-footed Frog
Litoria bicolor	northern Sedgefrog
Litoria caerulea	green Treefrog
Litoria coplandi	saxicoline Tree Frog
Litoria dahlii	northern Waterfrog
Litoria dorsalis	javelin Frog
Litoria inermis	bumpy Rocketfrog
Litoria meiriana	rockhole Frog
Litoria microbelos	dwarf Rocketfrog
Litoria nasuta	striped Rocketfrog
Litoria pallida	peach-sided Rocketfrog
Litoria personata	masked Cave Frog
Litoria rothii	red-eyed Treefrog
Litoria rubella	naked Treefrog
Litoria tornieri	Tornier's Frog
Litoria wotjulumensis	giant Rocketfrog
MICROHYLIDAE	**Narrow-mouthed frogs**
Austrochaperina aldelphe	northern territory frog
MYOBATRACHIDAE	**Southern frogs**
Crinia bilingua	ratchet frog
Limnodynastes convexiusculus	marbled frog
Limnodynastes ornatus	ornate burrowing-frog
Limnodynastes lignarius	carpenter frog
Notoden melanocaphus	brown orbfrog
Uperoleia arenicola	Jabiru toadlet
Uperoleia inundata	floodplain gungan
Uperoleia lithomoda	stonemason gungan

Site Non-waterbird List

Latin Name	Common Name
DROMAIIDAE	**Emus**
Dromaius novaehollandiae	emu
MEGAPODIIDAE	**Megapodes**
Megapodius reinwardt	orange-footed scrubfowl
PHASIANIDAE	**Pheasants and allies**
Coturnix chinensis	king quail
Coturnix pectoralis	stubble quail
Coturnix ypsilophora	brown quail
ACCIPITRIDAE	**Osprey, hawks and eagles**
Pandion haliaetus	osprey
Accipiter cirrhocephalus	collared sparrowhawk
Accipiter fasciatus	brown goshawk
Accipiter novaehollandiae	grey goshawk
Aquila audax	wedge-tailed eagle
Aviceda subcristata	pacific baza
Circus approximans	swamp harrier
Elanus axillaris	black-shouldered kite
Erythrotriorchis radiatus	red goshawk
Haliaeetus leucogaster	white-bellied sea-eagle

Latin Name	Common Name
Haliastur indus	brahminy kite
Haliastur sphenurus	whistling kite
Hamirostra melanosternon	black-breasted buzzard
Hieraaetus morphnoides	little eagle
Lophoictinia isura	square-tailed kite
Milvus migrans	black kite
FALCONIDAE	**Falcons**
Falco berigora	brown falcon
Falco cenchroides	nankeen kestrel
Falco hypoleucos	grey falcon
Falco longipennis	Australian hobby
Falco peregrinus	peregrine falcon
Falco subniger	black falcon
OTIDIDAE	**Bustards**
Ardeotis australis	Australian bustard
TURNICIDAE	**Button-quails**
Turnix castanota	chestnut-breasted button-quail
Turnix maculosa	red-backed button-quail
Turnix pyrrhothorax	red-chested button-quail
Turnix velox	little button-quail
BURHINIDAE	**Stone-curlews**
Burhinus grallarius	bush stone-curlew
COLUMBIDAE	**Pigeons and doves**
Chalcophaps indica	Emerald dove
Ducula bicolor	pied imperial pigeon
Geopelia cuneata	diamond dove
Geopelia humeralis	bar-shouldered dove
Geopelia striata	peaceful dove
Geophaps smithii	partridge pigeon
Ocyphaps lophotes	crested pigeon
Petrophassa rufipennis	chestnut-quilled rock-Pigeon
Phaps chalcoptera	common bronzewing
Phaps histrionica	flock bronzewing
Ptilinopus cinctus	banded fruit-dove
Ptilinopus regina	rose-crowned fruit-dove
CACATUIDAE	**Cockatoos**
Cacatua galerita	sulphur-crested cockatoo
Cacatua roseicapilla	galah
Cacatua sanguinea	little corella
Calyptorhynchus banksii	red-tailed black cockatoo
PSITTACIDAE	**Parrots**
Aprosmictus erythropterus	red-winged parrot
Platycerus venustus	northern rosella
Psephotus dissimilis	hooded parrot
Psitteuteles versicolor	varied lorikeet
Trichoglossus haematodus	rainbow lorikeet
CUCULIDAE	**Old World cuckoos**
Cacomantis variolosus	brush cuckoo
CENTROPODIDAE	**Coucals**
Centropus phasianinus	pheasant coucal
Chrysococcyx basalis	Horsfield's bronze-cuckoo
Chrysococcyx minutillus	little bronze-cuckoo
Chrysococcyx osculans	black-eared cuckoo

Latin Name	Common Name
Cuculus pallidus	pallid cuckoo
Cuculus saturatus	oriental cuckoo
Eudynamys scolopacea	common koel
Scythrops novaehollandiae	channel-billed cuckoo
STRIGIDAE	**Hawk owls**
Ninox connivens	barking owl
Ninox novaeseelandiae	southern boobook
Ninox rufa queenslandica	rufous owl
TYTONIDAE	**Barn owls**
Tyto alba	barn owl
Tyto capensis	grass owl
Tyto novaehollandiae	masked owl
PODARGIDAE	**Australian frogmouths**
Podargus strigoides	tawny frogmouth
CAPRIMULGIDAE	**Nightjars and allies**
Caprimulgus macrurus	large-tailed nightjar
Eurostopodus argus	spotted nightjar
AEGOTHELIDAE	**Owlet-nightjars**
Aegotheles cristatus	Australian owlet-nightjar
APODIDA	**Typical swifts**
Apus pacificus	fork-tailed swift
Hirundapus caudacutus	white-throated needletail
ALCEDINIDAE	**True kingfishers**
Alcedo azurea	azure kingfisher
Alcedo pusilla	little kingfisher
HALCYONIDAE	**Kingfishers and kookaburras**
Dacelo leachii	blue-winged kookaburra
Todiramphus chloris	collared kingfisher
Todiramphus macleayii	forest kingfisher
Todiramphus pyrrhopygia	red-backed kingfisher
Todiramphus sanctus	sacred kingfisher
MEROPIDAE	**Bee-eaters**
Eurystomus orientalis	dollarbird
Merops ornatus	rainbow bee-eater
PITTIDAE	**Pittas**
Pitta iris	rainbow pitta
CLIMACTERIDAE	**Australo-Papuan treecreepers**
Climacteris melanura	black-tailed treecreeper
MALURIDAE	**Fairy-, emu- & grass-wrens**
Amytornis woodwardi	white-throated grasswren
Malurus lamberti	variegated fairy-wren
Malurus melanocephalus	red-backed fairy-wren
Stipiturus ruficeps	rufous-crowned Emu-wren
PARDALOTIDAE	**Pardalotes, bristlebirds, scrubwrens and thornbills**
Gerygone levigaster	mangrove gerygone
Gerygone magnirostris	large-billed gerygone
Gerygone olivacea	white-throated gerygone
Gerygone chloronotus	green-backed gerygone
Smicrornis brevirostris	weebill
MELIPHAGIDAE	**Honeyeaters**
Certhionyx pectoralis	banded honeyeater
Conopophila albogularis	rufous-banded honeyeater

Latin Name	Common Name
Conopophila rufogularis	rufous-throated honeyeater
Entomyzon cyanotis	blue-faced honeyeater
Epthianura crocea	yellow chat
Lichenostomus unicolor	white-gaped honeyeater
Lichenostomus virescens	singing honeyeater
Lichmera indistincta	brown honeyeater
Manorina flavigula	yellow-throated miner
Meliphagia albilineata	white-lined honeyeater
Melithreptus albogularis	white-throated honeyeater
Myzomela erythrocephala	red-headed honeyeater
Myzomela obscura	dusky honeyeater
Philemon argenticeps	silver-crowned friarbird
Philemon buceroides	helmeted friarbird
Philemon citreogularis	little friarbird
Ramsayornis fasciatus	bar-breasted honeyeater
EOPSALTRIIDAE	**Robins and scrub-robins**
Eopsaltria pulverulenta	mangrove robin
Melanodryas cucullata	hooded robin
Microeca fascinans	jacky winter
Microeca flavigaster	lemon-bellied flycatcher
Poecilodryas superciliosa	white-browed robin
POMATOSTOMIDAE	**Australo-Papuan babblers**
Pomatostomus temporalis	grey-crowned babbler
NEOSITTIDA	**Sittellas**
Daphoenositta chrysoptera	varied sittella
PACHYCEPHALIDAE	**Whistlers, shrike-thrushes and allies**
Colluricincla harmonica	grey shrike-thrush
Colluricincla megarhyncha	little shrike-thrush
Colluricincla woodwardi	sandstone shrike-thrush
Falcunculus whitei	northern shrike-tit
Pachycephala lanioides	white-breasted whistler
Pachycephala melanura	mangrove golden whistler
Pachycephala rufiventris	rufous whistler
Pachycephala simplex	grey whistler
DICRURIDAE	**Monarchs, fantails and drongo**
Dicrurus bracteatus	spangled drongo
Grallina cyanoleuca	magpie-lark
Myiagra alecto	shining flycatcher
Myiagra inquieta	restless flycatcher
Myiagra rubecula	leaden flycatcher
Myiagra ruficollis	broad-billed flycatcher
Rhipidura dryas	arafura fantail
Rhipidura fuliginosa	grey fantail
Rhipidura leucophrys	willie wagtail
Rhipidura phasiana	mangrove grey fantail
Rhipidura rufiventris	northern fantail
CAMPEPHAGIDAE	**Cuckoo-shrikes and trillers**
Coracina maxima	ground cuckoo-shrike
Coracina novaehollandiae	black-faced cuckoo-shrike
Coracina papuensis	white-bellied cuckoo-shrike
Coracina tenuirostris	cicadabird
Lalage leucomela	varied triller

Latin Name	Common Name
Lalage sueurii	white-winged triller
ORIOLIDAE	**Orioles and figbirds**
Oriolus flavocinctus	yellow oriole
Oriolus sagittatus	olive-backed oriole
Sphecotheres viridis	figbird
ARTAMIDAE	**Woodswallows, butcherbirds and currawongs**
Artamus cinereus	black-faced woodswallow (nth sp)
Artamus leucorynchus	white-breasted woodswallow
Artamus minor	little woodswallow
Artamus personatus	masked woodswallow
Artamus superciliosus	white-browed woodswallow
Cracticus nigrogularis	pied butcherbird
Cracticus quoyi	black butcherbird
Cracticus torquatus	grey butcherbird
CORVIDAE	**Crows and allies**
Corvus orru	Torresian crow
PTILINORHYNCHIDAE	**Bowerbirds**
Chlamydera nuchalis	great bowerbird
ALAUDIDAE	**Old World larks**
Mirafra javanica	singing bushlark
MOTACILLIDAE	**Old World wagtails and pipits**
Anthus novaeseelandiae	Richard's pipit
Motacilla tschutschenis	yellow wagtail
PASSERIDAE	**Sparrows, weaverbirds, waxbills and allies**
Erythrura gouldiae	Gouldian finch
Heteromunia pectoralis	pictorella mannikin
Lonchura castaneothorax	chestnut-breasted mannikin
Lonchura flaviprymna	yellow-rumped mannikin
Neochmia phaeton	crimson finch
Neochmia ruficauda ruficauda	star finch
Poephila acuticauda	long-tailed finch
Poephila personata	masked finch
Taeniopygia bichenovii	double-barred finch
DICAEIDAE	**Flowerpeckers**
Dicaeum hirundinaceum	mistletoebird
HIRUNDINIDAE	**Swallows and martins**
Cheramoeca leucosternus	white-backed swallow
Hirundo ariel	fairy martin
Hirundo nigricans	tree martin
Hirundo rustica	barn swallow
SYLVIIDAE	**Old World warblers**
Acrocephalus stentoreus	clamorous reed-warbler
Cincloramphus cruralis	brown songlark
Cincloramphus mathewsi	rufous songlark
Cisticola exilis	golden-headed cisticola
Cisticola juncidis laveryii	zitting cisticola
Megalurus timoriensis	tawny grassbird
ZOSTEROPIDAE	**White-eyes**
Zosterops luteus	yellow white-eye

Site Waterbird List

Latin Name	Common Name
ANSERANATIDAE	**Magpie geese**
Anseranas semipalmata	magpie goose
ANATIDAE	**Swans, geese and ducks**
Anas gracilis	grey teal
Anas querquedula	garganey
Anas superciliosa	pacific black duck
Aythya australis	hardhead
Dendrocygna arcuata	wandering whistling-duck
Dendrocygna eytoni	plumed whistling-duck
Malacorhynchus membranaceus	pink-eared duck
Nettapus pulchellus	green pygmy goose
Tadorna radjah	radjah shelduck
PODICIPEDIDAE	**Grebes**
Poliocephalus poliocephalus	hoary-headed grebe
Tachybaptus novaehollandiae	Australasian grebe
ANHINGIDAE	**Darters**
Anhinga melanogaster	darter
PHALACROCORACIDAE	**Cormorants**
Phalacrocorax melanoleucos	little pied cormorant
Phalacrocorax sulcirostris	little black cormorant
Phalacrocorax varius	pied cormorant
PELECANIDE	**Pelicans**
Pelecanus conspicillatus	Australian pelican
ARDEIDAE	**Herons, bitterns and egrets**
Ardea alba	great egret
Ardea ibis	cattle egret
Ardea intermedia	intermediate egret
Ardea pacifica	white-necked heron
Ardea picata	pied heron
Ardea sumatrana	great-billed heron
Butorides striata	striated heron
Egretta garzetta	little egret
Egretta novaehollandiae	White-faced heron
Egretta sacra	eastern reef egret
Ixobrychus flavicollis	black bittern
Nycticorax caledonicus	nankeen night heron
THRESKIORNITHIDAE	**Ibises and spoonbills**
Platalea flavipes	yellow-billed spoonbill
Platalea regia	royal spoonbill
Plegadis falcinellus	glossy ibis
Threskiornis molucca	Australian white ibis
Threskiornis spinicollis	straw-necked ibis
CICONIIDAE	**Storks**
Ephippiorhynchus asiaticus	black-necked stork
GRUIDAE	**Cranes**
Grus rubicunda	brolga
RALLIDAE	**Rails, gallinules and coots**
Eulabeornis castaneoventris	chestnut Rail
Fulica atra	Eurasian coot
Gallirallus philippensis	buff-banded rail
Porphyrio porphyrio	purple swamphen

Latin Name	Common Name
Porzana cinerea	white-browed crake
Porzana pusilla	Baillon's crake
SCOLOPACIDAE	**Sandpipers and allies**
Arenaria interpres	ruddy turnstone
Limicola falcinellus	broad-billed sandpiper
Xenus cinereus	terek sandpiper
Actitis hypoleucos	common sandpiper
Calidris acuminata	sharp-tailed sandpiper
Calidris canutus	red knot
Calidris ferruginea	curlew sandpiper
Calidris melanotos	pectoral sandpiper
Calidris ruficollis	red-necked stint
Calidris tenuirostris	great knot
Gallinago hardwickii	Latham's snipe
Gallinago megala	Swinhoe's snipe
Heteroscelus brevipes	grey-tailed tattler
Limosa lapponica	bar-tailed godwit
Limosa limosa	black-tailed godwit
Numenius madagascariensis	eastern curlew
Numenius minutus	little curlew
Numenius phaeopus	whimbrel
Tringa glareola	wood sandpiper
Tringa nebularia	common greenshank
Tringa stagnatilis	marsh sandpiper
Tringa totanus	common redshank
JACANIDAE	**Jacanas**
Irediparra gallinacea	comb-crested jacana
BURHINIDAE	**Stone-curlews**
Esacus neglectus	beach stone-curlew
HAEMATOPODIDAE	**Oystercatchers**
Haematopus fuliginosus	sooty oystercatcher
Haematopus longirostris	pied oystercatcher
RECURVIROSTRIDAE	**Stilts and avocets**
Himantopus himantopus	black-winged stilt
Recurvirostra novaehollandiae	red-necked avocet
CHARADRIIDAE	**Lapwings, plovers and dottrels**
Charadrius dubius	little ringed plover
Charadrius hiaticula	ringed plover
Charadrius ruficapillus	red-capped plover
Charadrius leschenaultii	greater Sand plover
mongolus mongolus	lesser Sand plover
Charadrius veredus	oriental plover
Elseyornis melanops	black-fronted dotterel
Erythrogonys cinctus	red-kneed dotterel
Pluvialis squatarola	grey plover
Vanellus miles	masked lapwing
GLAREOLIDAE	**Pratincoles**
Glareola maldivarum	oriental pratincole
Stiltia isabella	Australian pratincole
LARIDAE	**Skuas, gulls, terns and allies**
Chlidonias hybridus	whiskered tern
Chlidonias leucopterus	white-winged black tern
Larus novaehollandiae	silver gull

Latin Name	Common Name
Larus pacificus	pacific gull
Sterna bengalensis	lesser crested tern
Sterna bergii	crested tern
Sterna caspia	caspian tern
Sterna hirundo	common tern
Sterna nilotica	gull-billed tern
Sterna sumatrana	black-naped tern

Freshwater fish species list (derived from Bishop *et al.* 2001)

Latin name	Common name
Carcharhinidae	
Carcharhinus leucas	river whaler or bull shark
Pristidae	
Pristis microdon	river sawfish
Dasyatidae	
Dasyatis fluviorum	brown river stingray
Megalopidae	
Megalops cyprinoides	tarpon
Clupeidae	
Nematalosa erebi	bony bream
Nematalosa come	bony bream
Hilsa kelee	black-spotted bream
Osteoglossidae	
Scleropages jardinii	saratoga
Ariidae	
Arius leptaspis	lesser salmon (forktailed) catfish
Arius proximus	grey (forktailed) catfish
Arius graeffei	blue (forktailed) catfish
Plotosidae	
Anodontiglanis dahli	toothless catfish
Neosilurus sp. A	eel-tailed catfish
Neosilurus sp. B	eel-tailed catfish
Porochilus obbesi	Obbes' catfish
Neosilurus sp. C	eel-tailed catfish
Neosilurus ater (3 colour types)	narrow-fronted tandan
Neosilurus hyrtlii (3 colour types)	Hyrtl's catfish
Porochilus rendahli (3 colour types)	Rendahl's catfish
Hemirhamphidae	
Zenarchopterus caudovittatus	garfish
Melanotaeniidae	
Melanotaenia nigrans	black-banded rainbow fish
Melanotaenia splendida inornata	chequered rainbowfish
Melanotaenia splendida australis	red-tailed rainbowfish
Atherinidae	
Craterocephalus marianae	Mariana's hardyhead
Craterocephalus stercusmuscarum	fly-specked hardyhead
Pseudomugilidae	
Pseudomugil tenellus	dainty blue-eye
Synbranchidae	
Ophisternon gutturale	swamp eel or one-gilled eel
Ambassidae	sail-fin perchlet or sail-fin glassfish

Latin name	Common name
Ambassis agrammus	
Ambassis macleayi	reticulated perchlet or reticulated
Denariusa bandata	pennyfish
Centropomidae	
Lates calcarifer	barramundi
Ambassidae	
Ambassis elongatus	yellow-fin perchlet or elongated
Terapontidae	
Amniataba percoides	black-striped grunter or banded grunter
Hephaestus fuliginosus	black grunter or bream
Hephaestus carbo	**black grunter or bream**
Leiopotherapon unicolor	spangled grunter
Syncomistes butleri	sharp-nosed grunter or Butler.s grunter
Pingalla midgleyi	Midgley's grunter
Apogonidae	
Glossamia aprion	mouth almighty
Toxotidae	
Toxotes lorentzi	primitive archerfish
Toxotes chatareus	common archerfish
Toxotes jaculator	archerfish
Scatophagidae	
Scatophagus argus	butter fish or scat
Mugilidae	
Liza alata	Ord River mullet
Liza parmata	green-backed mullet
Rhinomugil nasutus	mud mullet
Liza macrolepis	mullet
Gobiidae	
Glossogobius giuris	flathead goby
Glossogobius aureus	golden goby
Eleotrididae	
Hypseleotris compressa	empire gudgeon
Mogurnda mogurnda	purple-spotted gudgeon
Oxyeleotris lineolata	sleepy cod
Oxyeleotris nullipora	**poreless gudgeon**
Prionobutis microps	small-eyed sleeper or gudgeon
Oxyeleotris selheimi	black-banded gudgeon
Belonidae	
Strongylura krefftii	freshwater longtom
Soleidae	
Aseraggodes klunzingeri	tailed sole
Brachirus salinarum	salt-pan sole
Cynoglossidae	
Cynoglossus heterolepis	tongue sole

Status of Wetland Dependent Vertebrate Fauna
Table Notes:
Column 1 – legislative status under the EPBC Act (VU: vulnerable; M: migratory).
Column 2 – legislative status under the TPWCA (EN: endangered; VU: vulnerable; DD: data deficient).
Column 3 – inclusion under international bilateral agreement (C: CAMBA; J: JAMBA; R: ROKAMBA; B: Bonn Convention)

Scientific Name	Common Name	1	2	3
Mammals				
Myotis moluccarum	northern myotis			
Pipistrellus westralis	mangrove pipistrelle			
Hydromys chrysogaster	water-rat			
Xeromys myoides	water mouse	VU	DD	
Reptiles				
Crocodylus johnstoni	freshwater crocodile			
Crocodylus porosus	saltwater crocodile			
Carrettochelys insculpta	pig-nosed turtle			
Chelodina burrungandjii				
Chelodina rugosa	northern long-necked turtle			
Elseya dentata	northern snapping turtle			
Elseya jukesi				
Elseya latisternum	saw-shelled turtle			
Emydura victoriae	northern red-faced turtle			
Varanus indicus	Mangrove monitor		VU	
Varanus mertensi	Merten's water monitor			
Varanus mitchelli	Mitchell's water monitor			
Liasis fuscus	water python			
Acrochordus arafurae	arafuran file snake			
Acrochordus granulatus	little file snake			
Boiga irregularis	brown tree snake			
Ceberus rynchops	bockadam			
Enhydris polyepis	Macleay's water snake			
Fordonia leucobalia	white-bellied mangrove snake			
Myron richardsonii	Richardson's mangrove snake			
Tropidonophis mairii	leelback			
Frogs				
Cyclorana australis	giant frog			
Cyclorana longipes	long-footed frog			
Litoria bicolor	northern sedgefrog			
Litoria caerulea	green treefrog			
Litoria coplandi	saxicoline tree frog			
Litoria dahlii	northern waterfrog			
Litoria dorsalis	Javelin frog			
Litoria inermis	bumpy rocketfrog			
Litoria meiriana	rockhole frog			
Litoria microbelos	dwarf rocketfrog			
Litoria nasuta	striped rocketfrog			
Litoria pallida	peach-sided rocketfrog			
Litoria personata	masked cave frog			
Litoria rothii	red-eyed treefrog			
Litoria rubella	naked treefrog			
Litoria tornieri	Tornier's frog			
Litoria wotjulumensis	giant rocketfrog			
Austrochaperina aldelphe	Northern Territory frog			
Crinia bilingua	ratchet frog			
Limnodynastes convexiusculus	marbled frog			
Limnodynastes ornatus	ornate burrowing-frog			
Limnodynastes lignarius	carpenter frog			

Scientific Name	Common Name	1	2	3
Notoden melanocaphus	brown orbfrog			
Uperoleia arenicola	Jabiru toadlet			
Uperoleia inundata	floodplain gungan			
Uperoleia lithomoda	stonemason gungan			
Waterbirds				
Anseranas semipalmata	magpie goose	M		B
Anas gracilis	grey teal	M		
Anas querquedula	garganey	M		C,J,R,B
Anas superciliosa	pacific black duck	M		
Aythya australis	hardhead	M		
Dendrocygna arcuata	wandering whistling-duck	M		
Dendrocygna eytoni	plumed whistling-duck	M		
Malacorhynchus membranaceus	pink-eared duck	M		
Nettapus pulchellus	green pygmy goose	M		
Tadorna radjah	radjah shelduck	M		
Poliocephalus poliocephalus	hoary-headed grebe			
Tachybaptus novaehollandiae	Australasian grebe			
Anhinga melanogaster	darter			
Phalacrocorax melanoleucos	little pied cormorant			
Phalacrocorax sulcirostris	little black cormorant			
Phalacrocorax varius	pied cormorant			
Pelecanus conspicillatus	Australian pelican			
Ardea alba	great egret	M		C,J
Ardea ibis	cattle egret	M		C,J
Ardea intermedia	intermediate egret			
Ardea pacifica	white-necked heron			
Ardea picata	pied heron			
Ardea sumatrana	great-billed heron			
Butorides striata	striated heron			
Egretta garzetta	little egret			
Egretta novaehollandiae	white-faced heron			
Egretta sacra	eastern reef egret			C,B
Ixobrychus flavicollis	black bittern			
Nycticorax caledonicus	nankeen night heron			
Platalea flavipes	yellow-billed spoonbill			
Platalea regia	royal spoonbill			
Plegadis falcinellus	glossy ibis	M		C,B
Threskiornis molucca	Australian white ibis			
Threskiornis spinicollis	straw-necked ibis			
Ephippiorhynchus asiaticus	black-necked stork			
Grus rubicunda	brolga	M		
Eulabeornis castaneoventris	chestnut rail			
Fulica atra	Eurasian coot			
Gallirallus philippensis	buff-banded rail			
Porphyrio porphyrio	purple swamphen			
Porzana cinerea	white-browed crake			
Porzana pusilla	Baillon's crake			
Arenaria interpres	ruddy turnstone	M		C,J,R,B
Limicola falcinellus	broad-billed sandpiper	M		C,J,R,B
Xenus cinereus	terek sandpiper	M		C,J,R,B
Actitis hypoleucos	common sandpiper	M		C,J,R,B
Calidris acuminata	sharp-tailed sandpiper	M		C,J,R,B
Calidris canutus	red knot	M		C,J,R,B
Calidris ferruginea	curlew sandpiper	M		C,J,R,B
Calidris melanotos	pectoral sandpiper	M		J,R,B

Scientific Name	Common Name	1	2	3
Calidris ruficollis	red-necked stint	M		C,J,R,B
Calidris tenuirostris	great knot	M		C,J,R,B
Gallinago hardwickii	Latham's snipe	M		C,J,R,B
Gallinago megala	Swinhoe's snipe	M		C,J,R,B
Heteroscelus brevipes	grey-tailed tattler	M		C,J,R,B
Limosa lapponica	bar-tailed godwit	M		C,J,R,B
Limosa limosa	black-tailed godwit	M		C,J,R,B
Numenius madagascariensis	eastern curlew	M		C,J,R,B
Numenius minutus	little curlew	M		C,J,R,B
Numenius phaeopus	whimbrel	M		C,J,R,B
Tringa glareola	wood sandpiper	M		C,J,R,B
Tringa nebularia	common greenshank	M		C,J,R,B
Tringa stagnatilis	marsh sandpiper	M		C,J,R,B
Tringa totanus	common redshank	M		C,R,B
Irediparra gallinacea	comb-crested jacana			
Esacus neglectus	beach stone-curlew			
Haematopus fuliginosus	sooty oystercatcher			
Haematopus longirostris	pied oystercatcher			
Himantopus himantopus	black-winged stilt	M		
Recurvirostra novaehollandiae	red-necked avocet	M		
Charadrius dubius	little ringed plover	M		C,J,R,B
Charadrius hiaticula	ringed plover	M		C,J,R,B
Charadrius ruficapillus	red-capped plover	M		
Charadrius leschenaultii	greater sand plover	M		C,J,R,B
Mongolus mongolus	lesser sand plover	M		C,J,R,B
Charadrius veredus	oriental plover	M		R,B
Elseyornis melanops	black-fronted dotterel	M		
Erythrogonys cinctus	red-kneed dotterel	M		
Pluvialis squatarola	grey plover	M		C,J,R,B
Vanellus miles	masked lapwing	M		
Glareola maldivarum	oiental pratincole			C,J,R,B
Stiltia isabella	Australian pratincole			
Chlidonias hybridus	whiskered tern			
Chlidonias leucopterus	white-winged black tern	M		C,J,R,B
Larus novaehollandiae	silver gull			
Larus pacificus	pacific gull			
Sterna bengalensis	lesser crested tern			C
Sterna bergii	crested tern			J
Sterna caspia	caspian tern	M		C
Sterna hirundo	common tern	M		C,J,R,B
Sterna nilotica	gull-billed tern			
Sterna sumatrana	black-naped tern	M		C,J,B
Non-waterbirds				
Pandion haliaetus	osprey	M		B
Haliaeetus leucogaster	white-bellied sea-eagle	M		C,B
Haliastur indus	brahminy kite	M		
Alcedo azurea	azure kingfisher			
Alcedo pusilla	little kingfisher			
Todiramphus chloris	collared kingfisher			
Epthianura crocea tunneyi	yellow chat	VU	EN	
Eopsaltria pulverulenta	mangrove robin			
Pachycephala lanioides	white-breasted whistler			
Pachycephala melanura	mangrove golden whistler			
Rhipidura phasiana	mangrove grey fantail			
Myiagra alecto	shining flycatcher			

APPENDIX D: ENDEMIC SPECIES DISTRIBUTIONS

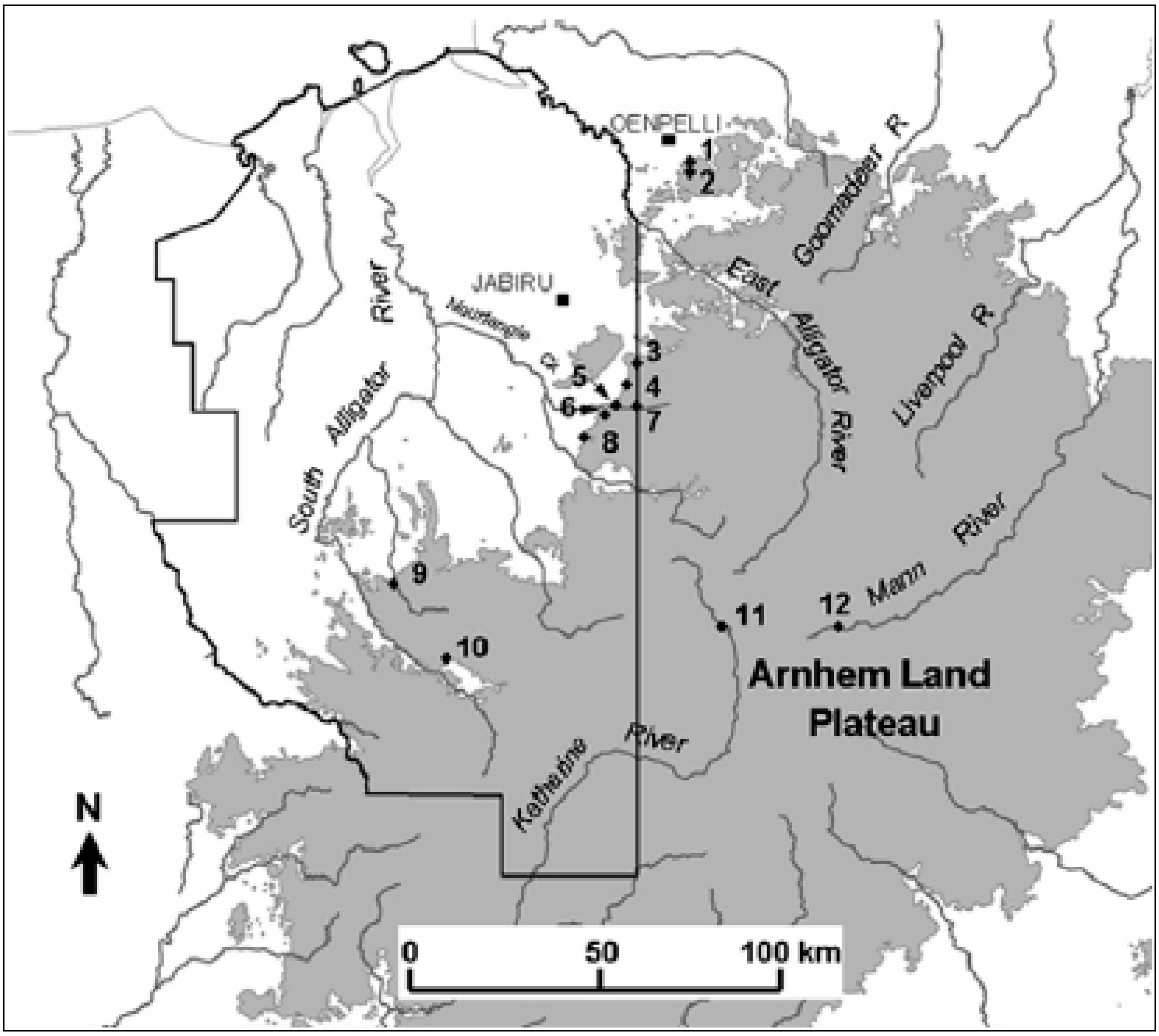

Figure D1 Records of the endemic shrimp family Kakaducarididae (source: Page *et al.* 2008)

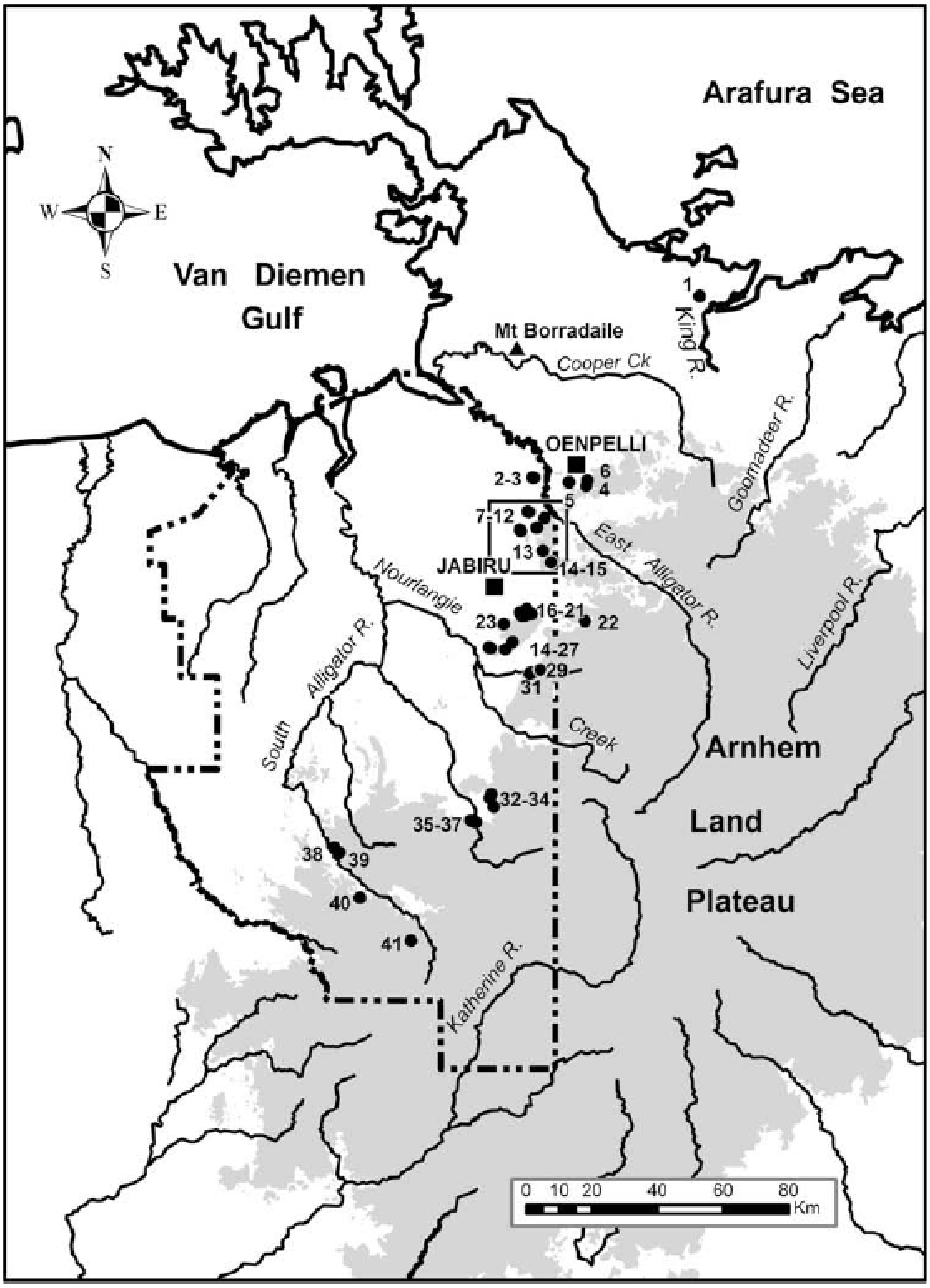

Figure D2 **Records of the endemic isopod genus *Eophreatoicus* (source: Wilson *et al.* 2009)**

Table D-1 Known locations where endemic aquatic invertebrate taxa occur in Kakadu (based on Bruce 1993, Page *et al.* 2008, Wilson *et al.* 2009)

Family	Species	Locations
Kakaducarididae (freshwater shrimp)	*Leptopalaemon gagadjui*	• Namarrgon Gorge • Nourlangie Plateau (south of Namarrgon Gorge) • Upper Barramundi Creek • Freezing Gorge (tributary of Koolpin Creek)
	Kakaducaris glabra	• Lightning Dreaming Creek (Namarrgon Gorge)
Phreatoicidae (freshwater isopods)	*Eophreatoicus* spp. (~30 undescribed lineages)	• Nourlangie Rock Cave • Nanguluwur • Nawurlandja cave stream • Twin Falls • Blue Tongue Dreaming Creek, Mt. Brockman • Lightning Dreaming Creek • Dinner Creek • Stockyard Creek (Cannon Hill/Hawke Dreaming) • Creek north of Namarrkon Gorge • Leichhardt Springs • Jackpot Creek • Dogleg Creek • Catfish Creek • Radon Springs tributaries • Gulungul Creek tributary • Wirnmuyurr Creek • North Magela tributary • Ngarradj Creek Spring • Jabiluka Outlier tributaries
Leptophlebiidae (mayflies)	*Tillyardophlebia dostinei*	• Rockhole Mine Creek (no known locations outside of Kakadu National Park)
	Other species from Leptophlebiidae (most likely regionally endemic rather than locally endemic)	• Gubara (Baroalba Springs) • Gulungul Creek (Radon Springs) • Magela Creek • South Alligator River (Koolpin Crossing) • South Alligator River (Gunlom Road Crossing) • Coobanrbora Spring • Koolpin Gorge • Kambolgie Creek • Jim Jim Creek

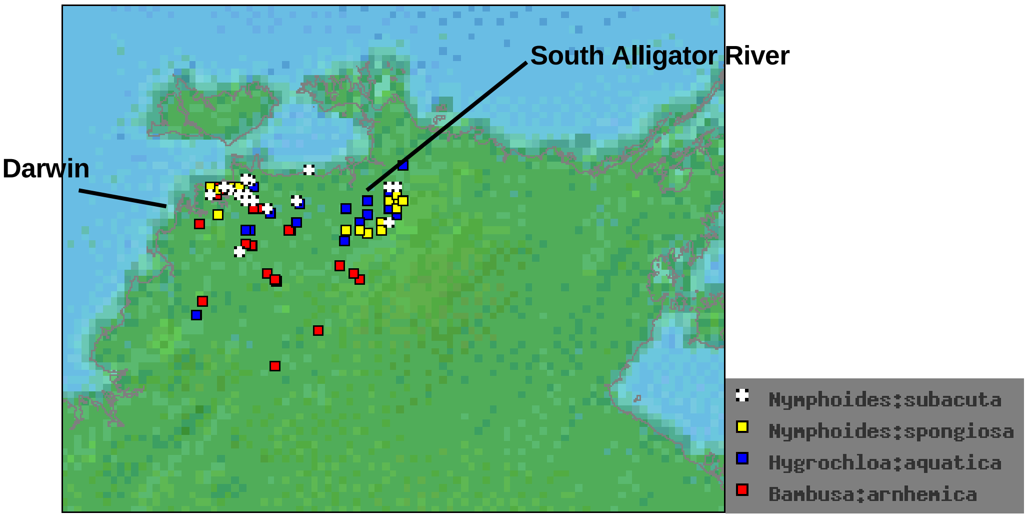

Figure D3 Records for wetland flora species of the Ramsar site that are endemic to the Timor Sea Drainage Division (source: Australia's Virtual Herbarium)

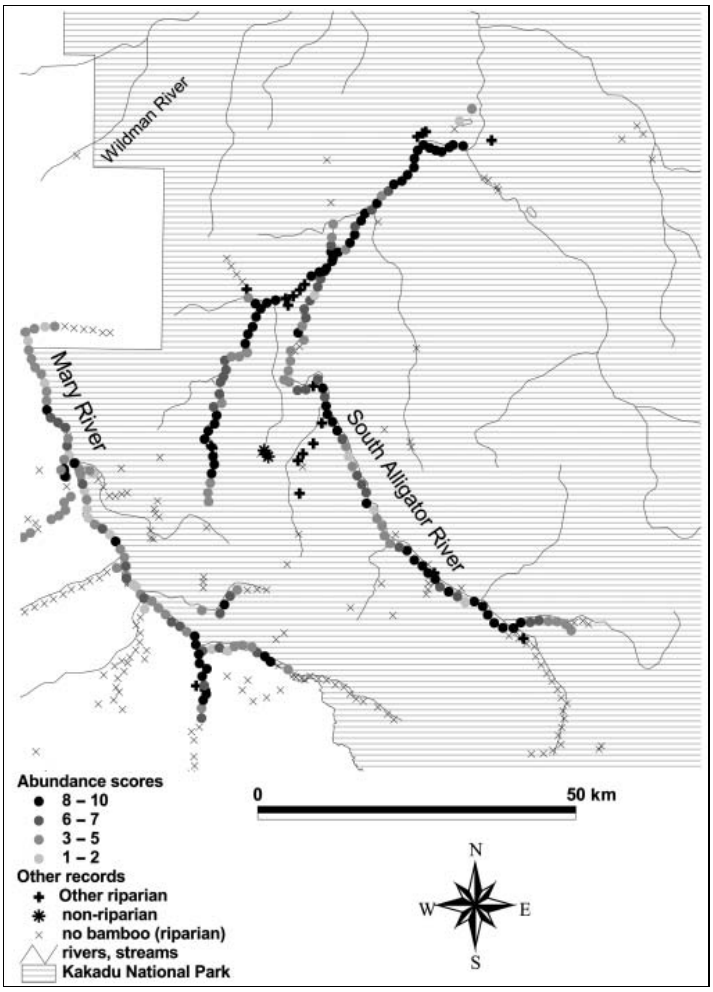

Figure D4 Abundance of *Bambusa arnhemica* along the South Alligator River (source: Franklin and Bowman 2004)

Table D-2 Endemic fish species records for Kakadu National Park (source: NAFF Fish Atlas)

Species	Wildman	West Alligator	South Alligator	East Alligator
Total no. fish	23		54	73
Total no. sites sampled	3	1	80	98
Magela hardyhead	No records	No records	Jim Jim Creek (2) Nourlangie Creek (2) Upper South Alligator (>15)	Magela (3) Cooper (1 site)
Sharp-nose/Butler's grunter	No records	No records	Jim Jim Creek (2) Nourlangie Creek (7) Upper South Alligator (>15)	Magela (7)
Exquisite rainbowfish	No records	No records	Jim Jim Creek (3)	No records
Midgley's grunter	No records	No records	Upper South Alligator (10) Jim Jim Creek(3) Nourlangie Ck (7)	Magela (10)

Numbers in parentheses represents the number of sampling localities at which species has been recorded.

APPENDIX E: CURRICULUM VITAE OF PRIMARY AUTHORS

BMT WBM

A part of BMT in Energy and Environment

Dr Darren Richardson

Position Associate
Manager Ecology and Environmental Management

Years of Experience 17

Professional Affiliations Member Environment Institute of Australia and New Zealand (EIANZ)

Qualifications Doctor of Philosophy, Southern Cross University (1998)

Bachelor of Applied Science, Honours (Class 1) University of New England (1992)

Bachelor of Applied Science, University of New England (1991)

Recent Employment Profile 1997 to Present
BMT WBM Pty Ltd – *Benthic Ecologist, Manager Marine and Aquatic Ecology (2002)*

1993 to 1997
Southern Cross University – *Consultant Aquatic Ecologist*

Career Overview

Darren is an Associate and Manager of Ecology at BMT WBM, and has over 17 years experience in research and environmental consulting. Darren undertook full-time post-graduate research between 1992 and 1997, which culminated in a First Class Honours degree in science from the University of New England, and a Doctor of Philosophy degree in marine ecology from Southern Cross University. During these post-graduate studies, he had various part-time, research assistant and consultant aquatic ecologist roles.

Darren commenced employment as a consultant aquatic ecologist at BMT WBM in 1997. Darren was appointed Manager of the Ecology group and made an Associate at WBM in January 2002. Darren's fields of expertise covers all aspects of freshwater, estuarine and marine ecology, with a focus on environmental impact assessment and management. Darren is also experienced in designing statistically rigorous environmental monitoring programs using a range of statistical techniques relevant to ecological and impact assessment studies.

Areas of Expertise

Marine, Estuarine and Freshwater Ecology

Assessment of Aquatic, Marine and Fisheries Habitat Conditions and Values

Biological Monitoring using Macroinvertebrates

Population Ecology

Environmental Impact Assessment

Specific Projects

Port and Dredging Related Assessments
- Alcoa Sediment and Biota Contamination Assessment (2008-ongoing)
- Ecological Assessments of the Port of Brisbane Seawall and Adjacent Habitat (2008-ongoing)
- DEWHA Technical Reviewer (2006-ongoing)
- Port of Townsville Expansion Preliminary Design (2008-ongoing)

Marine/Estuary Environment Impact Assessments and Monitoring (Non-Dredging)
- Corner Inlet Ramsar Site Monitoring Plan (2008)
- Calypso Bay Habitat Management Plan (2007-2008)
- Boggy Creek Discharge Monitoring (2008)
- Kedron Brook Mangrove Rehabilitation Study (2007)

Estuary Management Studies
- National Case Study – Effects of Climate Change on Kakadu Wetlands (2008-ongoing)
- Woronora River Estuary Processes Study (2005)
- Richmond River Estuary Processes Study (2005)
- Nambucca River Estuary Management and Study (2005)

Water Infrastructure
- Brisbane Desalination Site Study (2008)
- Gladstone-Fitzroy Pipeline EIS (2007-2008)
- Wyaralong Dam EIS (2006-2007)
- North Stradbroke Borefield Extraction EIS (2007)

Freshwater Ecology – Mining and Infrastructure
- Stanwell Power Station TEP (2008-ongoing)
- Goonyella Riverside Mine Water Quality Guidelines Assessment (2008)
- Yarraman Mine Water Quality Guidelines Assessment (2008)
- Moranbah North Mine – Assessment of Aquatic Ecosystems within a Subsidence Area (2006)

Freshwater Ecology – Non-Mining Assessments
- Moreton Bay Ramsar Site Ecological Character Description (2008)
- Currawinya Lakes Ramsar Site Ecological Character Description (2008)
- Ramsar Wetland National Snapshot Assessment (2007)
- Clarence and Tweed River Diversion REF (2007)

State of Environment Assessments
- State of the Catchment Report – Lake Samsonvale Catchment (2001)
- State of the Environment Report – Caboolture Shire (2000)
- State of the Rivers and Estuaries Report – NSW South Coast (1999)

Reef Ecology and Marine Habitat Conservation
- Moreton Bay Marine Park Habitat Mapping Study (2007-2008)
- Inventory and Assessment of Intertidal Rocky Shores of South-East Queensland (1998-1999)
- Influence of Benthic Community Structure on Reef Fishes on Moreton Island Reefs (1995-ongoing)

Key Publications/Presentations

Schlacher, T., Richardson, D. L., and McLean, I. (2008) Impacts of off-road vehicles (ORVs) on macrobenthic assemblages on sandy beaches. Environmental Management. 41(8): 878-892.

Richardson, D.L. (1999). Correlates of environmental variables with patterns in the distribution and abundance of two anemonefishes (Pomacentridae: Amphiprion) on an eastern Australian sub-tropical reef system. Environmental Biology of Fishes. 55: 255-263

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Greg Fisk

Position	Manager Environmental Planning
Years of Experience	15
Professional Affiliations	Environment Institute of Australia and New Zealand Australian Coastal Society
Qualifications	Masters Degree (Marine Policy) University of Delaware, USA (1996) Bachelor of Arts (Marine Science Affairs) University of Miami, USA (1994)
Recent Employment Profile	2007 to Present BMT WBM Pty Ltd – *Manager Environmental Planning* 2005 to 2007 Brisbane Airport Corporation – *Land and Marine Impacts Co-ordinator, New Parallel Runway Project* 1996 to 2005 Environmental Protection Agency – *Manager (2003), Senior Principal/ Policy Advisor (2000) - Environmental Planning Division*

Career Overview

Greg is an Associate and the Manager of Environmental Planning at BMT WBM, with over 15 years of experience in preparing, assessing and managing multi-disciplinary environmental plans and impact assessment studies.

With experience obtained in a variety of public and private sector positions, Greg has broad expertise in environmental planning and policy development, strategic resource assessment and environmental impact assessments, particularly with regard to wetlands and coastal management.

Since joining BMT WBM in 2007, Greg has been involved in several large-scale infrastructure EIS projects in the transport and energy sectors as well as a range of integrated natural resource assessments in the areas of wetland ecology, waterway management and climate change.

Areas of Expertise

Legislation, Policy and Planning

Marine, Coastal and Wetland Resource Assessment

Environmental Impact Assessment

Business Development

Climate Change Risk Assessment

Workshop/Expert Elicitation

Multi-disciplinary Studies and Project Management

Specific Projects

Resource Assessment
- Kakadu Ecological Character Description 2009 – ongoing)
- Shoalwater and Corio Bays Ecological Character Description (2009 – ongoing)
- Gippsland Lakes / Corner Inlet Ecological Character Description (2008 – ongoing)
- National Coastal Vulnerability Assessment, Kakadu (2008–ongoing)
- Moreton Bay Ecological Character Description (2008)
- Currawinya Lakes Ecological Character Description (2007-2008)

EIS and Approvals
- Cooktown Long Term Dredging and Dredge Spoil Management Strategy (2007–ongoing)
- SUN LNG Plant EIS, Gladstone (2007-2008)
- Marine Extraction Material Allocation Process (2007)
- New Parallel Runway Project EIS (2005–2007)
- Port of Townsville Preliminary Engineering and Environment Study (2008-2009)

Planning and Policy Development
- Port Stephens Climate Change Risk Assessment (2009)
- Development of Freshwater Wetland Regulatory Code – Queensland DERM (2009)
- Northshore Hamilton Land Use Master Plan (2008)
- Policy Review for Artificial Waters – Queensland EPA (2008)
- Development of Water Quality Objectives under the EPP Water (2004–2005)
- Operational Policy Reform – Queensland Parks and Wildlife Service (2002)
- Development and Implementation of Queensland Coastal Legislation Reform (2000–2003)
- Development of the Queensland Coastal Policy (State Coastal Management Plan) (2000–2002)

Key Papers/Publications

Fisk, G.W. (2008) 'National Coastal Policy – Issues for Consideration'.
Presented at the National Coast to Coast Conference 2008. Darwin, Northern Territory.

Fisk, G.W. (2004) 'Integrated Coastal Zone Management – the Queensland Experience".
Presented at the Coastal Zone Asia Pacific Conference 2004. Brisbane, Queensland.

Fisk, G.W. (2002) 'Regulation of development on Queensland's coast under the Coastal Protection and Management Act'.
Presented at the Coast to Coast 2002 Conference. Tweed Heads, New South Wales.

"Perceptions of the Performance of State Coastal Zone Management Programs in the United States. II. State and Regional Analysis" Robert W. Knecht, Biliana Cicin-Sain, Co-authors. *Coastal Management* Volume 25, No. 3, 1997: pp. 325 - 343.

"Policy Issues in the Development of Marine Biotechnology: A Global Perspective" Co-author with Cicin-Sain, Knecht, and Bouman *Ocean Yearbook 12*, 1996.

Lindsay Agnew

austecology

Position Director, Austecology

Qualifications B.Sc (Ecology and its Applications, Griffith University (1990))

Professional Affiliations
Ecological Society of Australia
Australian Society of Herpetologists
Australasian Bat Society
Queensland Wader study Group and Birds Australia

Fields of Special Competence

- Terrestrial fauna habitat assessment, impact assessment and management
- Conservation significance and biodiversity values assessment
- Habitat management & planning for natural & reconstructed environments
- Expert witness

Employment History

2007 onwards Director and Principal Zoologist, Austecology
2004 - 2007 Director and Principal Terrestrial Ecologist - Ecoserve
1998 - 2004 Associate & Principal Terrestrial Zoologist - WBM
1990 - 1998 Ecologist - Brisbane City Council; Field Research Officer - Griffith University; Consultant Ecologist - Lone Pine Koala Sanctuary

CONSULTANCY PROJECT EXPERIENCE POST 2005 – Part Listing

Significant Species Assessments

- Wet Season Ornamental Snake Surveys of Offset Areas – BMA Norwich Park (2010).
- Wet Season Black-throated Finch Surveys and Habitat Assessment – Lot 286 EP1901, Lot 1 RP742554, Lot 5 RP46633 and Lot 10 SP136003, Mount Low (2010).
- Wallum Sedgefrog Surveys & Habitat Assessments - Sunshine Motorway Duplication (Kawana Way to Mooloolah River Interchange) (2010).
- Wet Season Ornamental Snake Surveys – BMA Poitrel Leases (2010).
- Habitat Assessments - Threatened & Migratory Wetland-dependent Fauna – Splitters Creek, Rockhampton (2010).
- Koala Survey and Habitat Investigation – Warner Movieworld land holdings, Nerang (2010).
- Wallum Sedgefrog Surveys & Habitat Assessments - Multi-Modal Transport Corridor (Main Drive- Maroochy Boulevard) (2010-).
- Black-throated Finch and Threatened Species Surveys – Lot 666 SP122698, Mt. Louisa, Townsville (2009-)
- Koala Habitat Values Assessment - Investa Property Group landholdings at Palmview, Caloundra (2009).
- Koala Habitat Values Assessment – Lot 137 SP169488, Buckley Road, Burpengary (2009).
- Rare and Threatened Fauna Survey – Lot 367 CG286 and Lot 2 RP169511, Mt. Ninderry, Yandina (2009)
- Koala Habitat Mapping – Lots 1 & 2 RP886148, Wembley Rd, Berrinba.
- Threatened Reptile Survey and Habitat Values Assessment – Lot 1 RP737035, Cape Pallarenda (2009)
- Spotted-tail Quoll Surveys and Habitat Suitability Assessment – Round Ridge Road, Jimboomba (2009).
- Assessment of Potential Impacts to Capricorn Yellow Chat Habitat - Fitzroy River Water Extraction Project (2009).
- Ornamental Snake Surveys and Habitat Assessment – BMA Gregory Crinum (2009).
- Black-breasted Button-quail & Threatened Species Investigation – Mariners Cove, Eli Creek (2008)
- Assessment of Mahogany Glider & Cassowary Habitat Values – Hinchinbrook Habitats, Ingham (2008)
- Rare & Threatened Fauna and Biodiversity Surveys of the Willawa Nature Refuge, Theodore (2008)
- Wallum Acid Frog Surveys – Lands adjoining Pearce Avenue, Caloundra (2008)
- Surveys for Threatened Fauna & Biodiveristy – BMA Terang Leases, Blackwater (2008).
- Capricorn Yellow Chat Monitoring Surveys – GAWB Rockhampton to Gladstone Corridor (2007 - 2008).
- A Review of the Vulnerable Squatter Pigeon (southern subspecies) Records within Central Queensland and Plan to Model Potential Habitat Usage (2007).

- Threatened Fauna Species Assessments - Lot 9 on RP727756, Ryker's Road, Cape Tribulation (2007).
- Black-throated Finch Surveys and Habitat Assessment – Roseneath Quarry, Townsville (2007)
- Rare and Threatened Fauna and Flora Surveys – BMA South Walker Mine (2007).
- Wallum Froglet Population Monitoring Program for the Bundilla Heath Translocation Site (2006)
- Glossy Black-cockatoo Surveys and Habitat Values Assessments – Nathanvale, Gold Coast (2006).
- Assessment of Habitat Values for Species of Conservation Significance – Kawana Beach Site, Bokarina (2006).
- Grey-crowned Babbler Surveys & Conservation Management Plan – United Collieries, Hunter Valley (2005).
- Ornamental Snake Habitat Suitability & Impact Assessment – Moranbah to Newlands Rail Link (2005).
- Black-breasted Button-quail Management Plan – Lenthall's Dam (2005)
- Habitat Suitability Assessments for Macleay's Double-eyed Fig Parrot – Yorkey's Knob (2005).
- Survey of Vertebrate Fauna Diversity & Species of Conservation Significance – Indooroopilly Golf Course (2005)
- Threatened Species Assessment and Management Planning – BMA Terang leases (2005).
- Threatened Fauna Species and Vertebrate Biodiversity Survey of Lot 31 on RP 858565, Maroochy (2005)
- Assessment of Habitat Values for Species of Conservation Significance – East Pit, Curragh Mine (2005).

Natural Resource Inventories & Conservation Planning Studies

- Biodiversity Management Plan – BMA South Walker (2010 -)
- Biodiversity Management Plan – BMA Poitrel (2009 -)
- Kakadu Ramsar Site - Ecological Character Description Report and Information Sheet (2009 -)
- Dundowran Structure Plan - Fauna and Fauna Habitat Values – Fraser Coast Regional Council (2009).
- Gippsland Lakes Ramsar Site- Ecological Character Description Report and Information Sheet (2009 -)
- Biodiversity Management Plan – BMA Gregory Crinum (2009)
- Shoalwater Bay and Corio Bay Ramsar Sites - Ecological Character Description Report & Information Sheet (2009)
- Corner Inlet Ramsar Site - Ecological Character Description Report and Information Sheet (2009 -)
- Moreton Bay Ramsar Site - Ecological Character Description Report and Information Sheet (2008)
- Currawinya Lakes Ramsar Site - Ecological Character Description Report and Information Sheet (2008)
- Threatened Species and Biodiversity Action Plan – BMA Saraji (2006).
- Threatened Species and Biodiversity Action Plan – BMA Peak Downs (2006).
- Review of Habitat Values for Biodiversity & Species of Conservation Significance – BMA Poitrel Leases (2006).
- An Audit & Regional Overview of Biodiversity Values for BMA Coal Operations within Central Queensland (2006).
- Review of Habitat Values for Biodiversity & Species of Conservation Significance – BMA Terang Leases (2005).
- Review of Habitat Values for Biodiversity & Species of Conservation Significance – BMA Blackwater Mine (2005).
- Review of Habitat Values for Biodiversity & Species of Conservation Significance – BMA Saraji Mine (2005).
- Review of Habitat Values for Biodiversity & Species of Conservation Significance – Gregory Crinum Mine (2005).
- Review of Habitat Values for Biodiversity &Species of Conservation Significance – BMA Peak Downs Mine (2005).
- Review of Habitat Values for Biodiversity & Species of Conservation Significance – BMA South Walker Mine (2005).
- Review of Habitat Values for Biodiversity & Species of Conservation Significance – BMA Goonyella Riverside & Broadmeadows Mines (2005)
- Review of Habitat Values for Biodiversity and Species of Conservation Significance – Hay Point Facility (2005)

BMT WBM

A part of BMT in Energy and Environment

Megan Ward

Position Botanist

Years of Experience 5

Professional Affiliations Member of Ecological Society of Australia
Reviewer - *Heredity*

Qualifications Bachelor of Science (Botany) University of Natal (2002)

First Class Honours (Ecology & Conservation) University of Natal (2003)

Doctor of Philosophy Candidate, University of Queensland (2004-Present)

Recent Employment Profile

2008 to Present
BMT WBM Pty Ltd – *Botanist*

2006 to 2007
University of Queensland - *Tutor*

2004
CSIRO – *Technical Assistant*

2001 to 2002
University of Natal – *Teaching Assistant/ Research Assistant*

Career Overview

Megan commenced as a botanist with BMT WBM in early 2008. Since joining BMT WBM, Megan has been involved in a diversity of projects including vegetation assessments, monitoring programs and preparation of rehabilitation plans. This followed on from three years post-graduate experience at the University of Queensland, conducting field-based ecological research. Megan has previously held positions with CSIRO and the University of Natal (South Africa).

Areas of Expertise

Vegetation survey and mapping

Targeted flora species searches

Conservation value assessment

Impact assessment

Vegetation management and rehabilitation

Weed dispersion and population dynamics

Specific Projects

Biological Monitoring
- Tennyson Riverside Development Marine Plant Monitoring (2008-ongoing)
- Goonyella Riverside Mine Aquatic and Riparian Ecosystem Monitoring (2008-ongoing)
- Stanwell Power Station TEP (2008-ongoing)

Impact Assessments
- Waterway Impact Assessments of Wastewater Treatment Plants in Ipswich (2009-ongoing)
- Whyte Island Ecological Survey and Impact Assessment (2008)
- Brisbane Desalination Plant Siting Study (2008)
- GUP Mangrove Dieback Study (2008)

Targeted Species Search
- Angle-stemmed Myrtle Survey (2008)
- Bulimba State School Koala Habitat Survey (2009)

Environmental Audit
- OZ Minerals Pipeline Environmental Audit (2008)

Resource Assessment
- National Coastal Vulnerability Assessment, Kakadu (2008-ongoing)
- Shoalwater and Corio Bays Ecological Character Description (2008-ongoing)
- Gippsland Lakes and Corner Inlet Ecological Character Descriptions (2008-ongoing)
- Moreton Bay Ecological Character Description (2008)

Management and Rehabilitation Plans
- Nerang Street Bridge Replacement (2009-ongoing)
- Agnes Water and Town of Seventeen Seventy SEMP (2009-ongoing)
- Pacific Pines Catchment and Wetland Management Plan (2008-ongoing)
- Wetland Rehabilitation Plan for Inghams Enterprises, Murarrie (2008)
- Pimpama River Catchment Management Plan (2008)

Planning
- Northshore Hamilton Landuse Master Plan (2008)

Approvals
- Calypso Bay Concurrence Agency Matters – Vegetation Management (2009)

Key Papers/Publications

Ward, M. 2007. Is bigger always better? Reproductive Allee effects in invasive Asclepiads. Oral Presentation, 9th International Conference on the Ecology and Management of Alien Plant Invasions.

Ward, M., Dick, C.W., Gribel, R., and Lowe, A.J. 2005. To self or not to self... A review of outcrossing and pollen-mediated gene flow in neotropical trees. *Heredity* 95:246-254.

Lowe, A.J., Boshier, D., Ward, M., Bacles, C.F.E. and Navarro, C. 2005. Genetic resource impacts of habitat loss and degradation; reconciling empirical evidence and predicted theory for neotropical trees. *Heredity* 95:255-273.

Ward, M. and Johnson, S.D. 2005. Pollen limitation and demographic structure in small fragmented populations of *Brunsvigia radulosa* (Amaryllidaceae). *Oikos* 108:253-262.

Ward, M. 2003. The effects of habitat fragmentation on the reproduction and population demographics of *Brunsvigia radulosa* (Amaryllidaceae). Honours Thesis, University of Natal, South Africa.

BMT WBM

A part of BMT in Energy and Environment

Dr Markus Billerbeck

Position Senior Environmental Scientist

Years of Experience 8

Qualifications PhD (Aquatic Biogeochemistry) Max Planck Institute for Marine Microbiology, University of Bremen, Germany (2005)

Science Degree (Marine Biology) University of Rostock, Germany (2000)

Recent Employment Profile

2008 to Present
BMT WBM Pty Ltd – *Senior Environmental Scientist*

2008
CSIRO Land & Water – *Research Scientist*

2007 to 2008
Advanced Water Management Centre, University of Queensland – *Research Scientist*

2007
CSIRO Land & Water – *Research Scientist*

2001 to 2006
Max Planck Institute for Marine Microbiology (Germany) – *Research Scientist*

Career Overview

Markus is a Senior Environmental Scientist at BMT WBM and has more than 8 years experience in research and environmental science. Markus obtained a PhD in Aquatic Biogeochemistry at the Max Planck Institute for Marine Microbiology, Germany and a science degree from the University of Rostock, Germany. His main areas of expertise include the biogeochemistry and ecology of aquatic systems and the assessment of water quality and sediment parameters.

Markus has extensive experience in the development, organisation and implementation of complex field sampling and data collection in coastal seas, estuaries and rivers. His technical expertise includes deployment and measurements with Acoustic Doppler Profilers, multi-parameter probes and CTD's. Markus has also extensive experience working with benthic flux chambers, sediment core incubations and microsensor techniques.

Areas of Expertise

Aquatic Biogeochemistry and Aquatic Ecology

Integrated Stream Health Assessment

Microbial Activity in Sediments/Water Column

Coastal Nutrient and Carbon Cycling

Field Data Acquisition

Sampling and Measurements of Water Quality, Sediment and Oceanographic Parameters

Specific Projects

Port and Dredging Related Assessments
- Port of Townsville Expansion Project (2008-ongoing)
- Long Term Dredge Strategy: Mooloolaba Boat Harbour (2006-ongoing)

Marine/Estuarine Ecology Assessments
- Gippsland Lakes Ramsar Site Ecological Character Description (2009-ongoing)
- Corner Inlet Ramsar Site Ecological Character Description (2009-ongoing)

Environmental Impact Studies
- Olympic Dam – Environmental Impact Study (2009-ongoing)

Water Infrastructure
- Metocean Data Collection in Darwin Harbour (2008-ongoing)

Freshwater Ecology
- South Pine River – Sustainable Load Study (2009-ongoing)

Freshwater Biogeochemistry
- Tropical Rivers and Coastal Knowledge – Daly River, NT (2008-2009)

Marine/Estuarine Biogeochemistry
- eWater CRC – Ecological Management Project (2008)
- Fitzroy Flood Project
- Tully River Nutrient Load Study within Marine and Tropical Sciences Research Facility (2007)
- Biogeochemistry of the Wadden Sea, Germany (2001-2006)

Meteorology
- ATLANT Trial Wivenhoe/Somerset catchment, South East Queensland (2007)

Key Publications/Presentations

Jansen S., Walpersdorf E., Werner U., Billerbeck M., Boettcher M.E., de Beer D. (2009) Functioning of intertidal flats inferred from temporal and spatial dynamics of O_2, H_2S and pH in their surface sediment. Ocean Dynamics 59: 317-332.

Billerbeck M., Røy H., Bosselmann K., Huettel M. (2007) Benthic photosynthesis in submerged Wadden Sea intertidal flats. Estuarine Coastal & Shelf Science 71: 704-716.

Billerbeck M., Werner U., Bosselmann, K., Walpersdorf E., Huettel M. (2006) Nutrient release from an exposed intertidal sand flat. Marine Ecology Progress Series 316: 35-51.

Billerbeck M., Werner U., Polerecky L., Walpersdorf E., de Beer D., Huettel M. (2006) Surficial and deep pore water circulation governs spatial and temporal scales of nutrient recycling in intertidal sand flat sediment. Marine Ecology Progress Series 326: 61-76.

Werner U., Billerbeck M., Polerecky L., Franke U., Huettel M., van Beusekom J.E.E., de Beer D. (2006) Spatial and temporal patterns of mineralization rates and oxygen distribution in a permeable intertidal sand flat (Sylt, Germany). Limnology and Oceanography 51: 2549-2563.

A part of BMT in Energy and Environment

Dr Beth Hastie

Position Senior Marine Ecologist

Years of Experience 8

Professional Affiliations Ecological Society of Australia
Australian Marine Sciences Association

Qualifications Doctor of Philosophy (PhD) (2007)

Honours Degree (Science – First Class) (2002)

Bachelor of Science (2001)

Recent Employment Profile 2007 to Present
BMT WBM Pty Ltd – *Senior Marine Ecologist*

2002 to 2005
National Marine Science Centre – *Environmental Consultant and Academic Assistant*

2001
University of New England – *Research Assistant – Zoology & Ecology*

Career Overview

Beth is a Senior Marine Ecologist at BMT WBM Pty Ltd, with seven years post-graduate experience in ecological research and environmental consulting. Beth has a Class I Honours Degree, which examined human impacts on beach fauna communities. She also completed a Doctor of Philosophy (PhD) at the University of New England, specialising in intermittently closed estuaries and the impacts of environmental change on the faunal communities of these coastal waterways.

Beth has a thorough understanding of the ecology and management of coastal environments, as well as the complex interactions between terrestrial, estuarine and marine systems. She has hands-on experience conducting a variety of ecological research and monitoring projects in marine, estuarine, freshwater and beach environments.

Whilst at BMT WBM, Beth has worked on a broad range of projects, including those associated with catchment management and infrastructure planning for Local Governments; environmental impact assessments for State Government infrastructure development; and environmental assessment and monitoring for industry (e.g. mining, ports, private development).

Areas of Expertise

Expertise in Estuarine and Marine Ecology

Ecology of Coastal Waterways, Catchments and Beaches

Community Ecology and Impact Assessments

Aquatic Flora and Fauna Surveys and Assessments (e.g. benthic invertebrates, marine plants)

Specific Projects

Water and Linear Infrastructure
- Ipswich City Council STP Upgrade (2009)
- South Pine River STP Upgrade (2009)
- Landsborough to Nambour Rail Corridor EIS (2008)
- Visy Desalination Outfall Assessment (2008)
- Project Sun LNG Pipeline EIS - Aquatic Ecology Component (2008)
- Wyaralong Dam EIS and Baseline Report (2007)
- North Stradbroke Island Borefield Aquatic Fauna and Flora Assessment (2007)
- North-South Bypass Desalination Brine Outfall Investigation (2007)
- GAWB Water Pipeline (Fitzroy to Gladstone) EIS (2007)

Marine Plants
- GUP Mangrove Dieback Review (LAJV) (2008)
- Tennyson Riverside Development - Ecological Monitoring of Marine Plant Disturbance Works (Mirvac QLD) (2008-ongoing)
- Tennyson Riverside Development Mangrove Assessment (2007)
- Old Kedron Brook Mangrove Dieback Assessment (BAC) (2007)
- Port of Bing Bong Annual Seagrass Survey (2007)

Port and Airport Developments and/or Dredging
- Townsville Port Expansion Preliminary Engineering and Environmental Study (2009)
- Boggy Creek Benthic Monitoring (2008)
- Toondah Harbour Dredging Campaign Ammonia Monitoring (2008)
- Berth 12 Integrated Assessment – Port of Townsville (2008)

Waterway and Wetland Management
- Pacific Fair Ecological Assessment (Ocean Park Consulting) (2009)
- Gregory Crinum Mine Fish Kill (BMA) (2009)
- Pacific Pines Stormwater and Wetland Management Plan (GCCC) (2008-2009)
- Goonyella Riverside Mine (BMA) (2008)
- Warringah Lagoons Review of Entrance Management Practices (2007)
- Nerang Caravan Park Bridge Redevelopment (2007-2009)

Marine Habitat Mapping
- Port of Brisbane Habitat Assessment (POBC) (2009)
- Moreton Bay Marine Park Subtidal Habitat Mapping (2007)

Key Publications/Presentations

Hastie, B.F. & Smith, S.D.A. (2006) Benthic macrofaunal communities in intermittent estuaries during a drought: Comparisons with permanently open estuaries. *Journal of Experimental Marine Biology and Ecology*, Vol. 330, No. 1: 356-367.

Hastie, B.F. (2006) Spatial and temporal variation of benthic macrofaunal communities in the intermittently closed estuaries of the Solitary Islands Marine Park, Australia. PhD Thesis, University of New England, Armidale, New South Wales.

Hastie, B.F. (2001) The impact of 4WD vehicles on sandy beach macrofauna. Honours Thesis, University of New England, Armidale, New South Wales, Australia.

Also three non-refereed conferences publications and numerous consultancy reports and/or publications (both technical and non-technical).

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CURRICULUM VITAE
Michelle McKemey

CAREER SUMMARY

An Environmental Scientist with 12 years experience, I have worked throughout Australia and overseas on environmental projects. My strengths are ecology, natural resource management and monitoring, policy and planning, facilitation, communication and project management. With experience in the World Heritage Kakadu National Park, the Border Rivers Gwydir Catchment, the rapidly developing biodiversity hotspot of the Sunshine Coast and with endangered species in Africa and Asia, I have carefully grown the knowledge and skills to enable me to successfully develop and implement projects from diverse fields of environmental management.

EDUCATION

Bachelor of Science (Honours I), LaTrobe University (1999) and University of Queensland (1998)
Thesis – *Cross-cultural natural resource management: Aboriginal attitudes and management of feral animals around the Arafura Wetlands, NT*

PROFESSIONAL HISTORY

2008	Catchment Officer (PVP and Projects) Border Rivers Gwydir Catchment Management Authority, NSW

As a Catchment Officer I have worked with landholders to develop Property Vegetation Plans and provide advice on the management of native vegetation on their land in accordance with the *Native Vegetation Act 2003*. This has required the ability to learn and use the customised software PADACS to develop PVPs, to undertake data collection on vegetation and habitat values in the field and to liaise with internal and external stakeholders.

2003 & 2005 – 2008	Ecologist (2005 – 2008) Acting Program Coordinator- Biodiversity (2007) Environmental Research Officer (2003) Sunshine Coast Regional Council, Qld

As acting Program Coordinator I supervised ten officers and coordinated the multi-disciplinary projects of the biodiversity team. As an Ecologist I undertook environmental planning and policy, ecological assessments and managed restoration projects. My main projects comprised the development, implementation and contract supervision of the Maroochy Pest Management Plan, implementation of priority projects from the Maroochy Biodiversity Strategy, ecological assessments associated with conservation land and major infrastructure projects, coordination of fauna projects (koala mapping, marine turtle monitoring) and environmental education/communication projects. As an Environmental Research Officer I undertook the water quality monitoring program which involved collecting water samples, analysing results and presenting user-friendly reports. I developed a water quality education program which targeted the key causes of poor water quality. I also worked on mapping coastal vegetation and translating scientific knowledge into management actions. This position required the supervision of a school based trainee and volunteers from the Sunshine Coast University. During my employment with Sunshine Coast Regional Council I received accolades such as a 'Business Award' (2007) and 'Partnerships Award' (2005).

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CURRICULUM VITAE
Michelle McKemey

2003 – 2005 Kakadu National Park Officer
Department of Environment and Heritage / Northern Land Council, NT

I undertook consultation and facilitated decision making between the Aboriginal Traditional Owners, Kakadu Board of Management and Kakadu National Park management on issues such as natural and cultural resource management, tourism, business development, mining and research. Some projects in which I was involved were the Kakadu Plan of Management, Kakadu Shared Vision for Tourism, Twin Falls/Jim Jim Falls area planning, recruitment and environmental rehabilitation. This position required good communication skills, confidence and integrity.

2001 – 2002 Volunteer
Endangered species projects in Africa and Asia

At Oxford University's Budongo Forest Research Station in Uganda, I contributed to a study on the effects of landscape fragmentation on wildlife, including chimpanzees, through social surveys. In Namibia, I helped to radio-track the endangered black-faced impala and also supervised trainees in constructing a remote field camp and undertaking scientific surveys. In Malaysia I worked with researchers undertaking transect surveys through regrowth rainforest to determine the impacts on wildlife after logging. In Borneo I worked at the Sepilok Orangutan Rehabilitation Centre in animal care. I have also worked as a volunteer at Australia Zoo on the Sunshine Coast.

2000 Project Officer (Research)
Cooperative Research Centre for Sustainable Tourism, Qld

I provided executive support to the CEO and managed the Brisbane office of the CRC for Sustainable Tourism. I developed a communication program through contributions to Green Globe News, scientific journal articles, organising conferences and preparing keynote speaker presentations for international conferences. I undertook research into the environmental, social and cultural impacts of tourism and the development of indigenous tourism.

1996 – 2000 Project Officer
Australian Environment International, Qld

Throughout my university education and beyond, I worked with Australian Environment International on projects such as 'Selecting a site to test and model sustainability of grasslands in Queensland' and I undertook preliminary field research in Malaysia for environmental tourism planning. I was also involved in 'think tank' sessions at the business' head office in Brisbane and enjoyed the mentorship of the Chairman Dr Hugh Lavery for many years.

REFEREES

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