

Wetlands in the Arid Northern Territory



By

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David Albrecht, Jennifer Risler and Megan McNellie

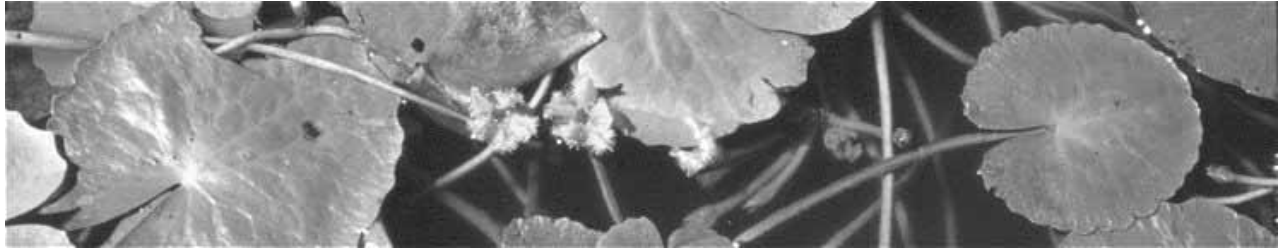


Northern Territory Government
Department of Natural Resources, Environment and the Arts

A report to the Australian Government Department of the Environment and Heritage,
for the project "Inventory and Significance of Wetlands in the Arid NT",
NT Project ID: 98017, Commonwealth Project ID: 13582,
carried out with assistance from the Natural Heritage Trust.



Natural Heritage Trust
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Biodiversity Conservation Unit, of the
Parks and Wildlife Service of the Northern Territory:
Northern Territory Government Department of Natural Resources Environment and the Arts

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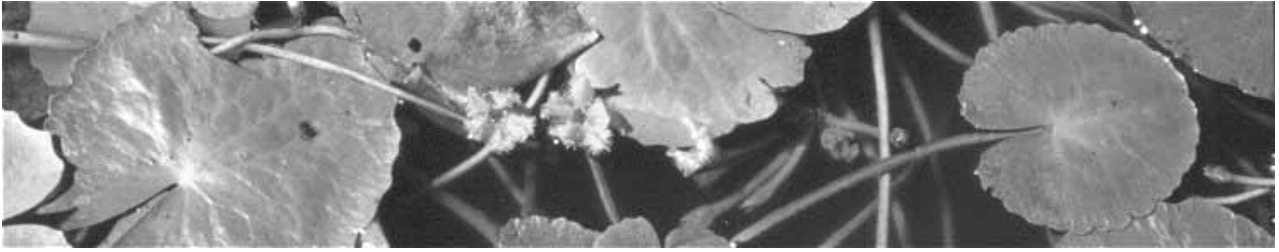


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There is a second volume of this report, to which access is restricted.

Volume 2: Information Collated for Individual Wetlands



Summary

This report describes the wetland values of the arid southern part of the Northern Territory; defined as south of twenty degrees of latitude (20°-26° S & 129°-138° E).

This vast and remote area, measuring about 900km by 650km and covering over 612,000km², has a predominately arid climate and there is a common perception that it has very few wetlands. This is far from the truth. A diverse array of wetland types are described here, including permanent, temporary, saline and fresh water wetlands. The vast majority of arid NT wetlands are episodic, filling occasionally and with water derived from rainfall within the region. Isolated in vast dry surrounding landscapes, these wetlands have a significant biological, economic and visual impact when inundated.

The information in this report is based on a two year inventory that was carried out with assistance from the Commonwealth Government through the Natural Heritage Trust, under the National Wetlands Program. The overall purpose of the inventory was to investigate and document the biological conservation values of wetlands in the study area and assess their national significance.

There has been no previous systematic wetland inventory of this area, or any of the essentially desert parts of Australia. This inventory has combined ground and aerial survey with remote (satellite) sensing and geographic information systems to define and describe the types of wetlands that exist, assess their general biological attributes, and to improve mapping of their distribution. One of the important outcomes has been the development of a functional classification that is relevant to local conditions and reflects local terminology whilst also being compatible with the international classification defined under the Ramsar Convention. The overall value of arid NT wetlands has been assessed for three key biotic groups: birds, plants and fish.

The significance of individual wetlands for conserving biodiversity is difficult to assess quantitatively. Individual wetlands have been assessed against the criteria for inclusion in *A Directory of Important Wetlands in Australia* and a subset have been assessed against the Ramsar criteria for internationally significant wetlands.

Four wetlands in the study area are described in *A Directory of Important Wetlands in Australia*. In this study, a further 47 wetlands of regional or national significance for the conservation of biodiversity have been identified. In some cases descriptions are of a wetland aggregation rather than an individual wetland. The identified significance of the described wetlands ranges greatly. About 30 are good examples of a wetland type in the region and are important elements in the regional wetland 'estate'; providing important habitat for wetland species of plants and animals. Many other wetlands in addition to those identified, are also important as elements in a network of scattered wetland habitat. About twenty of the newly identified important wetlands meet more objective criteria for conservation significance, such as supporting abundant waterbird life or providing core habitat for endemic or threatened species. Of these twenty, eleven wetlands have been identified as potentially meeting the Ramsar criteria for international significance. Subjective interpretation is required in applying some of the Ramsar criteria and so the assessments are not clear-cut.

None of the wetlands have been nominated for inclusion in *A Directory of Important Wetlands in Australia*, or for Ramsar listing. A process of consultation with landholders about possible nominations is proposed. For ten important wetlands, comprehensive descriptions have been prepared in the format used in *A Directory of Important Wetlands in Australia*.

Mapping of wetlands was carried out at a reconnaissance level using remote sensing techniques to analyse satellite images from 2 years of high rainfall. A great many previously unrecorded wetlands have been mapped and a small subset of these allocated to a wetland type. Some wetlands that were already mapped have had their boundaries revised and information recorded about inundation patterns. It was not possible

to obtain information about or map the outline of every wetland, and not possible to allocate every mapped wetland to a wetland type. Consequently it is likely that not all important wetlands have been identified.

The mapping component of the study also included a review of the extent of rivers where they flood out into deserts and the connectivity of river channels that flood out towards other rivers or waterbodies. This has resulted in a new understanding of drainage connectivity which is more coordinated than pre-existing mapping indicates. The boundaries of the nationally defined river basins were reviewed in the light of new information on drainage systems. Some minor changes and one major change are proposed to the existing boundaries, adding significantly to the size of the Lake Eyre Drainage Division.

The study included a review of wetland classification issues and proposes a classification system that will be effective for summarising and documenting the variety of wetland types in the arid NT. The system is semi-hierarchical and is suitable for adoption in any future, more detailed mapping of arid NT wetlands.

The occurrence and increasing infestation of exotic plant species has been confirmed as the major threat to natural values of wetlands in the study area. Human alterations to hydrological regimes such as water diversions and draining appear to be having little impact at present. The long-term impact of introduced herbivores is impossible to assess from a rapid reconnaissance level survey. A number of instances of landholders fencing wetland areas of their own volition is indicative of the high value that is often placed on natural and aesthetic values along with importance for domestic stock. Nevertheless, fresh water wetlands of virtually all types are focal points for domestic stock, for both food and water, and some adverse impact is inevitable.

Wetlands form a relatively small proportion of the landscape of the study area and most of them are dry most of the time. Nevertheless they support a diverse and distinctive range of plants and animals. The survey component of the inventory benefited greatly from being carried out in a period of extremely high rainfall across much of the study area. This resulted in most of the wetlands that were surveyed being observed whilst they were either inundated or whilst the effects of inundation were still evident in the vegetation.

Survey work was focused on defining wetland types and allocating individual wetlands to types, as well as assessing significance for biodiversity, condition and threats. The range of wetland types was sampled across most of the geographic spread of the study area. Survey work included counting wetland birds, recording plants species present, sampling aquatic invertebrates and fish and describing the soils, landform and vegetation structure.

Vegetation was the most consistently sampled part of wetland biota because it persists beyond periods of inundation and accordingly, has a key role in determining wetland types. A large amount of data has been collected for wetland plant species, adding to both distributional and ecological knowledge. Confirmed species records were obtained for 321 sites, including 269 threatened, rare or poorly known (data deficient) taxa. Over 800 voucher specimens have been lodged with the NT Herbarium, contributing to current and future taxonomic investigations.

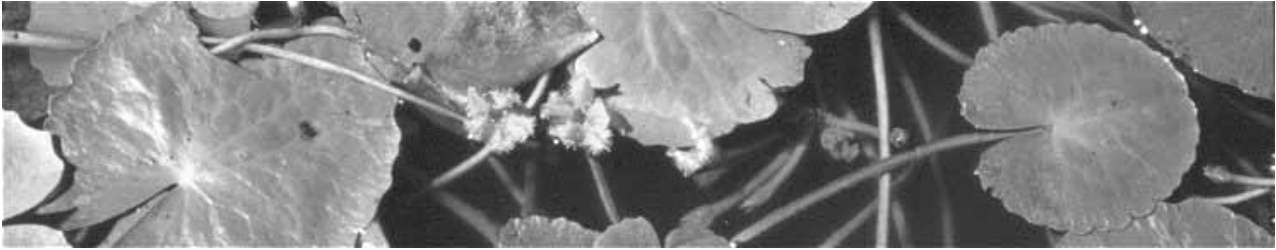
A preliminary list of wetland plants has been produced for the study area. A variety of nationally rare wetland plants grow in the study area, including some that are nationally vulnerable. Furthermore, there are populations of wetland plants that are significantly disjunct from their main populations and these may have distinct genetic compositions. This report also includes a summary of the major groups of wetland plants, providing an introduction to new workers in the area.

Waterbirds were recorded from ground, boat or aerial observation, at a total of 115 wetlands, contributing to both the NT Fauna Atlas and the national bird atlas (created by Birds Australia). Both new and pre-existing data were used to review current knowledge about wetland birds in the arid NT. New observations include significant records from areas that have been rarely-surveyed or never previously surveyed for waterbirds, including Lake Mackay and the inter-dune lakes of Snake Creek on the eastern floodout of the Finke River. The vast salt lakes in the west and south west of the study area have been confirmed as having national and international importance for wetland birds, with detailed counts at Lake Mackay and Lake Lewis. While many of these lakes only fill infrequently, when they are full they support many thousands of waterbirds and significant breeding events. Other wetland types have confirmed values for waterbirds, although, none support the vast populations of the salt lakes. However, compared to salt lakes, they are generally more frequently filled. They include waterholes in rivers, river

floodout swamps, Bluebush (*Chenopodium auricomum*) swamps, Coolabah swamps and various types of claypans, grassy, herbaceous and samphire swamps.

Fish and aquatic invertebrates were sampled opportunistically, however, a review of new and pre-existing data was conducted to summarise the distribution of species in the study area. This is combined with a review of the abundance and distribution of permanent waterbodies. Fish and invertebrate specimens have been lodged at museums or with other researchers. Fish were collected from several river systems for which no vouchered museum records previously existed. The first vouchered records were obtained of *Porochilus argenteus* in the Sandover River system and *Neosilurus hyrtili* in Kurundi Creek. Fish samples from the survey are contributing to genetic taxonomic-distribution work by Deakin University and the South Australian Museum. Aquatic invertebrates were collected at 85 sites and fishes collected at 53 sites. There are fish that are significantly disjunct from their main populations and these may have distinct genetic compositions. Indeed there are 3 species of fish which are endemic to the study area. At least one other fish is recognised as possibly distinct but has not been formally described. The aquatic invertebrate fauna of the study area is for the most part poorly known. Waterholes of the West MacDonnell Ranges and those of the George Gill Ranges have been previously surveyed for aquatic fauna and both areas have distinctive species assemblages, reflecting their geographic isolation and the presence of permanent pools or semi-permanent permanent pools and springs.

This report is in two volumes. Volume one is the main part and is for general public access. Volume 2 contains information collated about individual wetlands. It includes descriptions of important wetlands in the format required for inclusion in *A Directory of Important Wetlands in Australia*. Negotiations with landholders are ongoing for some sites and these are not to be included in the Directory without landholder permission. Accordingly Volume 2 is not for public access.



Acknowledgments

A great many people from a variety of professions and occupations have contributed to the work reported here. Peter Latz conducted survey work and assisted with plant identification. More importantly he generously shared his insights into arid NT wetlands, particularly in prioritising survey areas and in interpreting results. Roger Jaensch of Wetlands International played a valuable role in refining the scope of the project and the methodology to be employed. Roger provided a national and international wetland perspective to the task and also assisted with creating a working classification. Roger also provided valuable comments on a draft of this report. Graham Ride and Robert Read provided advice on aspects of hydrology. Robert Read also assisted with some of the survey work, and bird counts in particular and also assisted with descriptions of some wetlands that were not formally surveyed. The contributions of various museums in providing specimen records of fishes and aquatic invertebrates is acknowledged and particularly Helen Larson of the Northern Territory Museum. Dr. Mark Adams and Terry Sim of the South Australian Museum gave particular advice and encouragement regarding sampling of fishes. Dr. Jim Puckridge and Peter Hudson of Adelaide University advised on wetland sampling methodology. Rachel Paltridge undertook some of the survey work, identified invertebrate samples and conducted liaison with some traditional Aboriginal owners. Virginia Garner assisted with the laboratory testing of water samples for pH and conductivity. Ray Chatto was the bird observer for the Lake Mackay aerial survey. Various members of the feral camel aerial survey program assisted in recording wetlands but the roles of Keith Saalfeld and Dr. Glenn Edwards in allowing the feral camel survey to record valuable wetland data are particularly acknowledged. Ross Brian and Stephen Eldridge advised on the existence and condition of various tracks. Grant Allan provided advice on satellite imagery. Robert Henderson provided information on waterbodies and fish in the Alice Springs area. Dawn Morgan volunteered for a month of fieldwork and undertook the bulk of the data entry task. Bernadette Bostock and Stephen Ryan of Deakin University participated in some of the fieldwork with an emphasis on fish sampling and undertook identification of invertebrates. Stephen Ryan also assisted with obtaining museum fish records. The following people also took part in field survey work: John Westaway, Naomi Briggs, Michael Hewett, Michael Reiff, Robert Reiff, Greg O'Neil, Bernie Shakeshaft, Paddy Lewis Japanangka, Alice Michaels Nampitjinpa, Lindsay Turner Jampitjinpa, Mitjili Gibson Napanangka, Cindy Gibson Nakamarra and Letitia Bartlett Nungarrayi. Catherine Nano, Jeff Cole, Don Langford and their Finke Bioregion Survey team provided data and various services and information. Alison Kennedy, Mandy Bowman and Diana Whitehouse provided information on land unit mapping and Alison also advised on soil survey and analysis. Di Wade and Will Dobbie provided contact details for cattle stations. Jeff Turpin and Naomi Briggs assisted with soils analysis and Naomi Briggs assisted with data entry. Bradley Nott and colleagues at the Central Land Council assisted with consultation with traditional Aboriginal owners. Several property owners plus the Avon Downs police, provided the use of accommodation facilities. Sue Cawood provided office support including typing and data entry. Penny Johnston helped with proof reading. Kathy McConnell assisted with document production. Jodie Mason did the layout of the photographic wetland guide. Mark Harris determined the elevation data for the summary of major drainage lines. Dr Greg Leach, Dr Helen Neave and Dr Anthony Bowland provided managerial oversight of the project. Mark Richardson and Graham Phelps made staff from the Alice Springs Desert Park available for some survey trips and approved the secondment of Jason Barnetson to the project for 9 months. Hillary Coulson assisted in the Alice Springs Herbarium. Darren Schunke provided local knowledge of aquatic environments in the George Gill Range and Palm Valley area and Dennis Matthews provided additional information on the longevity of waterholes in the Palm Valley area. Various members of the PWCNT staff provided information on particular wetlands including Chris Day, Tim Hall and Michael Barritt.

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Roles of the Authors

All of the authors were members of staff in the Scientific Services Division of the Parks and Wildlife Commission of the Northern Territory (now called the Biodiversity Conservation Unit of the Parks and Wildlife Service of the NT, under the Department of Natural Resources, Environment and the Arts).

Angus Duguid was the project leader, with responsibility for project design, implementing the field program, data analysis and writing the report.

Jason Barnetson took part in a majority of survey trips, taking a lead role in bird observation and sampling aquatic life and soils. He had a major role in logistic support for the survey program as well as assisting in a great many other aspects, including data management and reporting of fish survey methods. Jason was on secondment from the Alice Springs Desert Park.

Dr. Bretan Clifford had a major role in extending the mapping of wetlands, using satellite imagery and geographic information systems, including the review of drainage connectivity and the boundaries of national drainage basins. He also took part in aerial survey and preparation of climatic data, maps and tables in the report.

Dr. Christoph Pavey had a major role in the review of wetland birds in the study area.

David Albrecht is the botanist at the Alice Springs Herbarium. He was involved in designing the botanical aspects of the field survey program, assisted with some wetlands specific field trips as well as surveying wetlands opportunistically whilst on general botanical field trips. He had the lead role in creating the list of wetland plants for the study area and in identifying pressed plant specimens.

Jennifer Risler took part in the field program as a botanist and in plant identification in the Herbarium.

Megan McNellie was involved in the early part of the study, collating and preparing satellite imagery and other geographical data as well as participating in preliminary field trips.



1. Introduction

1.1 Purpose, Scope and Objectives

This report summarises current knowledge of wetlands in the arid part of the Northern Territory, defined as that portion of the Northern Territory (NT) that is south of 20 degrees latitude (20° S). It is based on a project to inventory the wetlands and assess their significance for ecological conservation. The project was carried out with financial assistance from the Natural Heritage Trust (NHT), as part of the National Wetlands Program, administered by Environment Australia (now the Australian Government Department of the Environment and Heritage).

For the purpose of this document, wetlands are broadly defined as follows:

Wetlands are areas of permanent or temporary surface water or waterlogged soil. They may be dry for decades but inundation or water logging must be reoccurring and of sufficient duration to be used by macroscopic plants and animals that require such conditions during their lifecycles. They may be natural or artificial, with still or running water which can be fresh or saline. In the inland they may be of any depth or size.

A detailed discussion of wetland definition and classification are contained in the body of the report.

The primary purpose of the study was to obtain information needed to conserve the diversity of plants and animals that depend on arid NT wetlands. This meant collecting information about the types of wetlands that occur, where the wetlands are and what plants and animals they support.

The objectives of the project were as follows.

1. To develop a functional classification of wetland types for the arid zone.
2. To complete an inventory of arid zone wetlands (both natural and artificial), including creation of a revised digital map of wetlands.
3. To identify the biological values of a sample of these wetlands.
4. To identify wetlands where biological and conservation values satisfy criteria for recognition at the local, national and international levels, with particular emphasis on identifying additional wetlands for inclusion in *A Directory of Important Wetlands in Australia*.
5. To identify threats to these wetlands.
6. To provide advice to relevant landowners with regard to the management of wetlands.
7. To recommend ways for improving the management of important wetlands, particularly those with high conservation values.

These objectives were modified from those set out in the original NHT funding application. The modifications were made following further development of the scope and methods by the project team, including advice from Roger Jaensch (Jaensch 2000) and taking into account the contractual obligations to Environment Australia.

This inventory component of the project was at a reconnaissance level, consistent with the vast size of the area and the resources and time available. The inventory focused on defining wetland types, describing their key attributes, identifying good examples of each type, and revising mapping of wetlands. The mapping component included collating existing mapped outlines, using satellite imagery to identify additional wetlands and reviewing the boundaries of some that were already mapped. It was not possible to obtain information about or map the outline of every wetland, and not possible to allocate every mapped wetland to a wetland type. Consequently it is likely that not all important wetlands have been identified.

Most aspects of wetlands of the arid NT are poorly known, making assessment of significance difficult. An improved general understanding of the ecological functioning of arid NT wetlands is a prerequisite to adequately assessing their general importance and the relative importance of individual wetlands. Accordingly, this report includes some review and synthesis of information from various disciplines. It incorporates pre-existing information and data obtained from the survey and mapping conducted for the inventory. New contributions to knowledge of the distribution of wetland plants, birds, fish and aquatic invertebrates are reported in sections reviewing knowledge of each group. It is intended that the review components of the report will also assist and promote further study of wetland biology in the arid NT. For many aspects of wetlands ecology a comprehensive review is beyond the scope of this study. In these cases an overview has been provided.

No attempt has been made to document or collate cultural values of wetlands. It is widely recognised that wetlands in general were important areas for food and in the case of fresh water areas, for drinking water for Aboriginal people. Many wetlands are also of spiritual significance to Aboriginal people and of historical significance in exploration by non-aboriginal people. Occasional comments pertaining to these values were recorded during field survey when information was volunteered by landholders.

The wetland inventory was conducted concurrently with a biological survey of the Finke Bioregion, which was also assisted with funding from the Natural Heritage Trust. There was no overlap in field work of the two surveys but some synergy in sharing of the resulting data.

1.2 Overview of Content and Structure

This report is in two volumes. Volume one is the main part and is for general access. The content and structure of Volume 1 are summarised below.

The contractual arrangements with Environment Australia, the infrastructure, climate and terrain of the study area are described in this introductory section. Also, the policy context for wetlands conservation is discussed, along with a summary of the level of pre-existing knowledge and reasons that an inventory was needed.

The methods used to conduct the survey component of the inventory are presented with a brief review of the requirements for consistency with other inventories. Field survey focused on developing the classification of wetland types by assessing the wetland type or types of all wetlands surveyed. At a subset of these wetlands more detailed observations were made of various combinations of plants, birds, fish, aquatic invertebrates and soils, to provide a basis for describing wetland types and assessing conservation significance. Frogs and mammals were not studied in the project.

Separate chapters are presented for various subject areas covered in this report, and relevant results of the inventory are presented and discussed in each chapter.

An overview is given of the geomorphic, climatic and hydrologic origins of arid NT wetlands. This provides a basis for better understanding the ecological function of the wetlands, their geographic distribution and aspects of classifying wetland types. Some information is included on past climates and geology as both these subjects influence wetland geomorphology and also the biogeography of the wetland flora and fauna.

The drainage systems of the arid NT are summarised and reviewed, providing context for understanding wetland distribution and function. The division of the study area into national drainage divisions and basins is discussed. Some comments are made on drainage division and basin boundaries where there is evidence for improvements in mapping them.

A classification of wetlands of the arid NT is presented. The environmental attributes that are used to distinguish wetlands from other environments are reviewed, along with the issue of wetland definitions. Attributes that are used to distinguish the various wetland types are discussed and a description given of each type. The classification is relevant to local conditions and reflects local terminology whilst also being compatible with the international classification defined under the Ramsar Convention as applied by the Commonwealth Government.

A general summary of the field survey is presented, providing context for subsequent chapters on the main biotic groups: birds, plants, fishes, invertebrates and amphibious and terrestrial vertebrates. There is

a focus on those biotic groups that can currently be used to assess conservation significance. Where there is sufficient information, the importance of particular wetland types for biotic groups is discussed. Also, some aspects of relictualism and endemism are discussed.

A separate chapter is devoted to wetland mapping issues. This includes a review of pre-existing maps and other sources of information on wetland locations. A revised GIS coverage (digital map) of wetlands has been produced based on pre-existing mapping and the analysis of satellite imagery from 2 years of high rainfall. A great many previously unrecorded wetlands have been mapped, however, not many have been allocated to a wetland type. Also, many wetlands that were already mapped have had their boundaries revised and information about inundation patterns stored in a geographic information system.

The wetlands of each bioregion are summarised, with overviews of the terrain and a list of wetlands of regional or national significance for the conservation of biodiversity.

Threats to the conservation values of wetlands are described and recommendations given for further work.

Volume 2 contains information collated about individual wetlands. It includes descriptions of important wetlands in the format required for inclusion in A Directory of Important Wetlands in Australia. However, these descriptions are not to be included in the Directory without landholder permission. Landholders of properties where potential Directory wetlands occur have been advised of this but permission to list sites in the Directory has not yet been negotiated. Accordingly Volume 2 is not for public access, although it is hoped that much of the information within it will be available through the Directory in due course. Volume 2 also includes information collated for many wetlands, regardless of their significance. This includes a summary of the survey data on a site by site basis, prepared as feedback to landholders.

1.3 Contractual Arrangement

This document is the final report to the Australian Government Department of the Environment and Heritage on the project titled 'Inventory and Significance of Wetlands in the Arid NT'. The Northern Territory Project ID is 98017 and the Commonwealth Project ID is 13582.

The agreed scope of the project under the NHT funding is presented in table 1 below.

Table 1. Scope of project, from appendix 3.2 of the funding consultancy agreement.

Scope Item	Item Description
1	Complete an inventory of arid zone wetlands in the Northern Territory and identify the biological values of a sample of these wetlands. The project should focus on identifying wetlands in bioregions that are under-represented in A Directory of Important Wetlands in Australia (2 nd edn 1996).
2	Collate thematic and other available mapping to identify wetland features.
3	Survey identified wetlands using aerial and ground coverage. Select a sample of wetlands representing different types for more detailed survey of water quality, flora and macro fauna.
4	Analyse data and prepare a summary report. The report should provide details on a functional classification of wetland types in the arid zone which will be compatible with the forthcoming national wetlands inventory.
5	Identify any threats to the biological values of arid zone wetlands identified by the project and make recommendations concerning the management of these wetlands, particularly those with high conservation values. Provide advice to relevant landowners with regard to the management of these wetlands.
6	Prepare documentation for Northern Territory wetlands that satisfy criteria for listing in A Directory of Important Wetlands in Australia, or as Ramsar sites under the Convention on Wetlands (Ramsar, Iran 1971).

The project was proposed in an NHT funding application in 1998. The proposal was successful and the initial payment for the two year project was received in December 1998 by the Parks and Wildlife Commission of the Northern Territory. Due to delays in establishing the project team the reporting schedule was revised. The original proposal was for a project team of one and a half people, however, in order to achieve the objectives a larger team was formed, bringing a broad range of expertise to the task. During the preparation of this report, the Northern Territory Government has undertaken a series of

restructures of the public service. The Parks and Wildlife Commission has become the Parks and Wildlife Service and is part of a larger department, now configured as: the Department of Natural Resources, Environment and the Arts. Consequently the names Parks and Wildlife Service and Parks and Wildlife Commission are synonymous where used in this document.

1.4 Study Area Definition and Overview

The study area is that part of the Northern Territory to the south of twenty degrees of latitude (20° - 26° S & 129° - 138° E), shown in figure 1. It is greater than 612,000km² in size, measuring about 650km from north to south and 900km from east to west and constituting 45 % of the area of the NT. The area is divided into almost equal northern and southern halves by the Tropic of Capricorn (23° 26' S). The project title refers to the study area as the 'arid NT' which is consistent with common delineations of Australia's arid zone (see Albrecht *et al.* 1997), yet the northern part has a pronounced monsoon influence. The essentially arid climate means that the wetlands are typically temporary, however they include permanent springs and waterholes. The temporary wetlands range enormously in size and in the frequency and lengths of inundation but most are inundated episodically, not in a predictable annual seasonal pattern.

Important characteristics of the study area that constrain scientific research are the vast size, remoteness and very low population density.

The population of the study area is only about 40,000 people (population information supplied by Australian Bureau of Statistics); even though the area is about 8 % of the Australian landmass, over three quarters the size of New South Wales and is bigger than both Victoria and Tasmania, as shown in table 2. The only major urban centre is Alice Springs with a population of about 28,000, with a further 2,700 people in or near the tourist town of Yulara. The rest of the population mostly live in remote communities, cattle stations and a few mining settlements. The town of Tennant Creek is just north of the study area with a population of about 3,900.

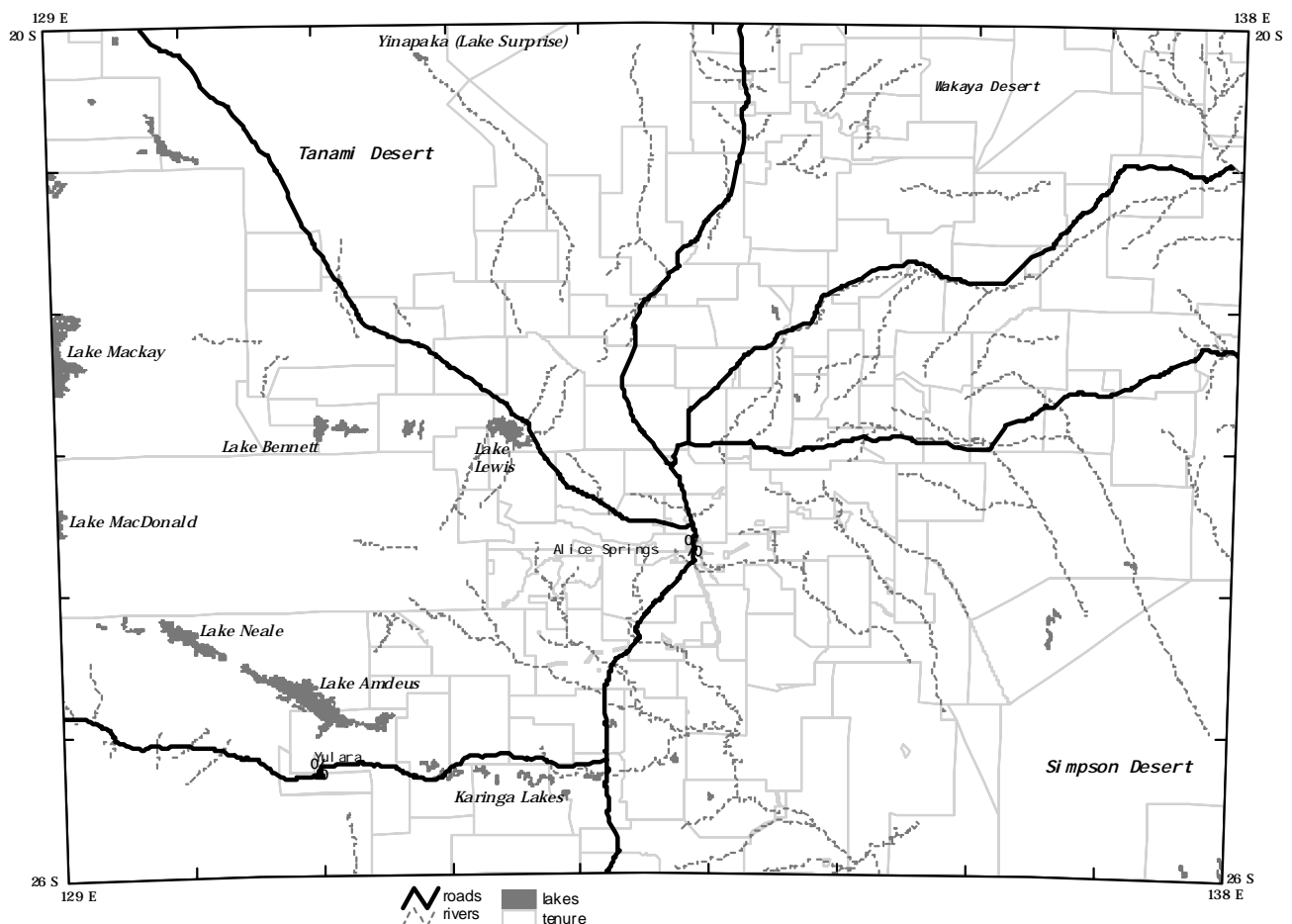


Figure 1. Map of the study area.

Table 2. Size of the study area and comparison with NT and the three smallest States.

	Size in km ²	Study area as proportion of others
Study Area	612, 830	
Northern Territory	1,349,129	0.45
New South Wales	800,642	0.77
Victoria	227,416	2.69
Tasmania	68,401	8.96
Australian mainland including Tasmania	7,659,861	0.08

Areas of states and mainland taken from the AUSLIG internet site:
<http://www.auslig.gov.au/facts/dimensions/areadime.htm>

Vehicular access across the study area is quite restricted and four wheel drives are required for many areas. There is a relatively limited network of public roads, station and other tracks, of which many are rarely used and are overgrown and/or washed out. Large areas are virtually untracked and rarely visited by people; particularly the Simpson Desert in the south east corner of the NT, much of the Great Sandy Desert in the west and the Tanami Desert in the north-west of the study area.

The two largest categories of land use and ownership in the study area are Aboriginal land and pastoral stations grazed for cattle production, with some overlap of the two. The third major category of land use-ownership is conservation reserve. Most of the land in this category is currently managed by the Parks and Wildlife Service of the Northern Territory or Parks Australia, with a variety of land tenures and owners, including Aboriginal Land. A third management group has entered the conservation reserve network with the purchase of the lease of Newhaven Station by Birds Australia.

The arid NT as defined for this study, overlaps with the area often referred to as 'central Australia'. The areas to which the term 'central Australia' refers varies quite widely with its use. We have avoided the term except where referring to information from sources which use it. The term is often used loosely to refer to the central part of the continent. The Flora of Central Australia (Jessop 1981) uses the term in the broadest sense; including much but not all of the Australian arid zone and also parts of the semi-arid zone in the Northern Territory and Queensland. Urban (1990) uses 'central Australia' to refer to the area defined here as the arid NT and Griffin and Friedel (1985) use the term to apply to a similar area.

1.5 Terrain and Bioregionalisation

The terrain of the arid NT is characterised by contrasts; with vast plains, dunefields, various large salt lakes and mountain ranges which rise abruptly from the plains. It is distinguished from the rest of the Australian arid zone by the occurrence of several major but isolated river systems that start and end in the arid zone. The overall abundance of ranges and their height also distinguishes the arid NT from the surrounding arid parts of New South Wales and Queensland and from most of South Australia and Western Australia. Also, the ranges of the MacDonnell Ranges Bioregion are unique in the Australian arid zone in their density, extent, height and isolation from the coast. The only other arid upland area of similar extent is Western Australia's Pilbara region which drains to the Indian Ocean. None of the arid NT mountains are high on a world scale but several ranges are significant on the Australian scale. The tallest are in the West MacDonnell Ranges, with the highest peak in the NT, Mount Zeil rising to 1531m above sea level (asl). It is the highest point on the continent that is not associated with the so called Great Dividing Range of eastern and south-eastern Australia. However, apart from the MacDonnell Ranges bioregion in the centre of the arid NT and the Davenport and Murchison Ranges in the north east, most of the area is of relatively low relief with ranges rising as scattered visually dominate features within predominantly flat plains and dune systems. The western half of the study area is also characterised by extensive systems of saline lakes, some of which are vast.

The study area is made up of eleven (11) biogeographical regions (bioregions) according to the Interim Biogeographic Regionalisation for Australia (IBRA). Ten of these were recognised at version 4.0 of IBRA (Thackway & Cresswell 1995) and an eleventh, Davenport Murchison Ranges, has since been

recognised under IBRA 5.0. The names and areas of the bioregions are given in table 3 and the distribution of each in the study area is shown in figures 1 and 2.

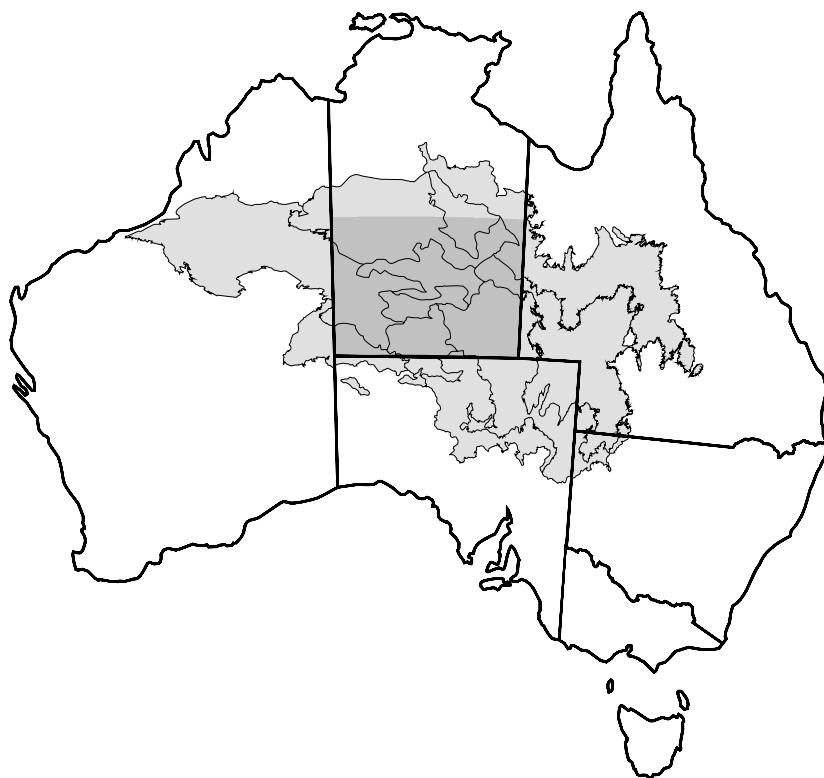
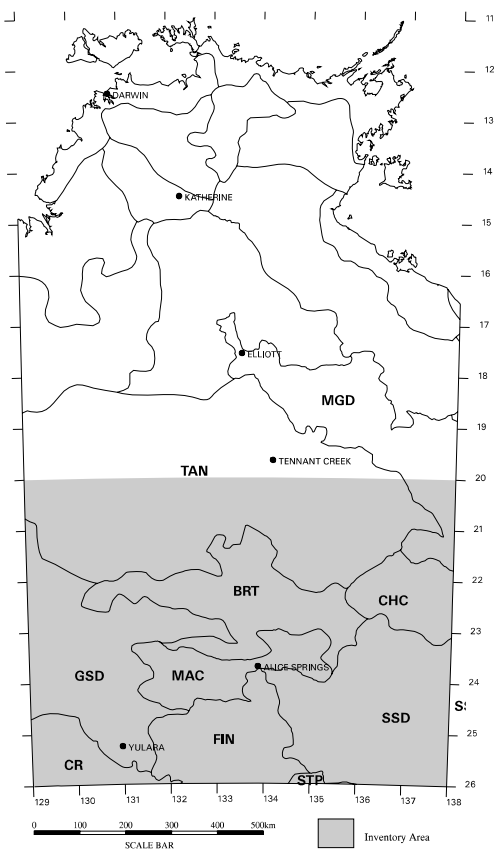


Figure 2. Continental extent of bioregions of the study area
The dark shading is the study area and the pale shading is the further extent of the bioregions.



The IBRA bioregions are part of the criteria for assessing the significance of wetlands for inclusion in a Directory of Important Wetlands in Australia. They are used in this report as a basis for reporting some of the inventory results. It is important to appreciate that many of the bioregions of the study area extend beyond it, as shown in figure 2 and table 2. Only three of the eleven bioregions are contained entirely within the study area: the Burt Plain, Davenport Murchison Ranges and MacDonnell Ranges bioregions. The other eight extend into the neighbouring states. One of these has only a very small part of its extent in the NT: the Stony Plains bioregion. Also, both the Tanami and Mitchell Grass Downs bioregions extend within the NT significantly further north of the study area.

Figure 3. Northern territory with extent of the arid NT and bioregion boundaries.
The dark shading is the study area and the pale shading is the further extent of the bioregions.

Table 3. Names and areas of bioregions (IBRA version 5) of the study area.

Bioregion Name (and Code)	Area in arid NT (km ²)	Area in Aus. (km ²) <i>Albers projn.</i>	% in arid NT	% in NT
Burt Plain (BRT)	73,797	73,797	100 %	100 %
Central Ranges (CR)	25,791	101,177	25 %	25 %
Channel Country (CHC)	23,271	284,754	8 %	8 %
Davenport Murchison Ranges (DMR)	27,790 (area in NT: 58,051)	58,051	48 %	100 %
Finke (FIN)	54,291	73,795	74 %	74 %
Great Sandy Desert (GSD)	99,840	395,250	25 %	25 %
MacDonnell Ranges (MAC)	39,294	39,294	100 %	100 %
Mitchell Grass Downs (MGD)	23,839 (area in NT: 93,062)	335,141	7 %	28 %
Simpson-Strzelecki Dunefields (SSD)	105,361	294,180	36 %	36 %
Stony Plains (STP)	1,697	134,196	1 %	1 %
Tanami (TAN)	137,649 (area in NT: 229,818)	259,974	53 %	88 %

Areas calculated using Albers Equal Area projection on a double precision Arc/Info GIS coverage. The coverage was obtained from the Environment Australia internet site: www.environment.gov.au/cgi-bin/edd/download.pl.

1.6 Climate

A good understanding of the climate of the arid NT is essential to understanding the distinctive character of its wetlands.

The climate of the study area is essentially hot and moderately arid, but with infrequent and highly unpredictable heavy rains (Stafford Smith & Morton 1990). Indeed, the variability of the climate is as important to wetland ecology as the generally low rainfall (Williams 1998a). The pulses of water availability that result from occasional heavy rains are of great importance in inundating wetlands. These pulses also sustain a relatively large biomass of perennial vegetation across the landscape, compared to many overseas arid areas, such that large parts of the Australian arid zone do not conform to popular conceptions of deserts (Williams & Calaby 1985).

There are various definitions and circumscriptions of the term 'arid zone' which are mostly based on rainfall and evaporation. Williams and Calaby (1985, p.269) define the Australian arid zone by 'the 254 mm rainfall isohyet in the south and east of the continent and the 381 mm isohyet in the north' based partly on the extent of arid vegetation formations. On that definition, and on the map of the arid zone in the Flora of Central Australia (Jessop 1981), most of the NT to the south of 20° latitude is arid, with the northern edge being semi-arid. Murrell (1984) defines the arid zone as extending to the 500 mm isohyet in the north, which approximates to that part of Australia which receives rainfall (at least 0.25 mm) on less than 50 days per year (on average). There is a useful brief summary of the arid NT climate in Finlayson *et al.* (1988). Slatyer (1962) provided a detailed early account in *Lands of the Alice Springs Area, Northern Territory, 1956-57* (Perry 1962). A general account of the climate of inland Australia is given in Williams and Calaby (1985) and a more recent and detailed account of Australian climate and the influence of global atmospheric and ocean systems is given in Hobbs (1998).

The climate of the arid NT is often described using statistics for Alice Springs, however, there is a distinct latitudinal gradient from the north to the south of the study area. The latitudinal gradient in various climatic parameters is illustrated in table 4 below with data from Kulgera on the South Australian border, Alice Springs and Tennant Creek, just to the north of the study area (only 38km north of 20°). It should be noted that latitude is not the only alignment of climatic gradients. At Alice Springs, rainfall and temperatures are strongly influenced by the elevation of the MacDonnell Ranges, such that the climate there is not representative of that latitude across the NT.

Table 4. Summary of climatic parameters at three latitudes.

Climatic Parameters		Kulgera 133° 18' E, 25° 51' S	Alice Springs 133° 53' E, 23° 49' S	Tennant Creek 134° 11' E, 19° 38' S
Elevation (metres above sea level)	m	509	546 *	376
Mean Annual Rainfall	mm	242	278	420
Median Annual Rainfall	mm	215	238	401
Mean Daily Maximum Temp January	°C	36.0	36.0	36.9
Mean Daily Maximum Temp July	°C	18.7	19.5	24.3
Mean Daily Minimum Temp January	°C	21.1	21.2	25.0
Mean Daily Minimum Temp July	°C	4.6	4.0	12.0
Highest Maximum Temperature	°C	45.5	45.2	44.7
Lowest Minimum Temperature	°C	-4.7	-7.5	4.5
Average Number of Frosts Per Year	days	22	31	0
Annual Average Areal Potential Evapotranspiration	mm	1,350	1,390	1,600
Annual Average Point Potential Evapotranspiration	mm	2,700	2,660	3,040

Sources: Climate of the NT (Bureau Of Meteorology 1998), Climatic Atlas of Australia (Bureau of Meteorology 2000 & 2001).

* Note that ranges adjacent to Alice Springs rise to 956m asl and at their highest the MacDonalld Ranges reach 1531m.

The mean annual rainfall ranges from greater than 400 mm per year in the north (20°S) to less than 200 mm per year in the south east corner (26°S). The southeast corner of the Northern Territory, in the Simpson Desert, is the driest part with a mean annual rainfall of less than 200 mm. The gradient of decreasing rainfall from north to south corresponds to distance from the coast, which is one of the global influences on aridity (Williams 1984).

The study area occurs in the transition zone between winter dominated rainfall in the south of the continent and summer dominated rainfall in the north. The southern half of the study area has a significant winter rainfall influence, however, most rainfall occurs in summer from a combination of monsoon influence and cloud banks associated with low-pressure systems. For example, Alice Springs gets more than twice as much rain in the summer months as in the winter. In comparison, the north of the study area gets nearly all its rain in the summer months, with only occasional winter rainfalls. The seasonality of rainfall in the study area is illustrated in figure 4 below.

Average point potential evapotranspiration greatly exceeds rainfall throughout the arid NT, with values ranging from around 2700 mm in the south to around 3100 mm in the north (Bureau Of Meteorology 2001). Potential evapotranspiration is the capacity of the air to absorb water evaporated from soil, surface waterbodies and plants (transpiration). The trend of increasing evaporation from south to north corresponds to increasing humidity along the same gradient. In central Australia the average point potential evaporation is generally more representative than areal potential evaporation, since actual evaporation is typically low. In the vicinity of large waterbodies and following exceptional rainfall events, actual evaporation may be best estimated by areal evaporation due to humidification of air masses as they cross wet or damp surfaces. Deep shaded gorges will also have evaporation rates that are substantially less than regional averages.

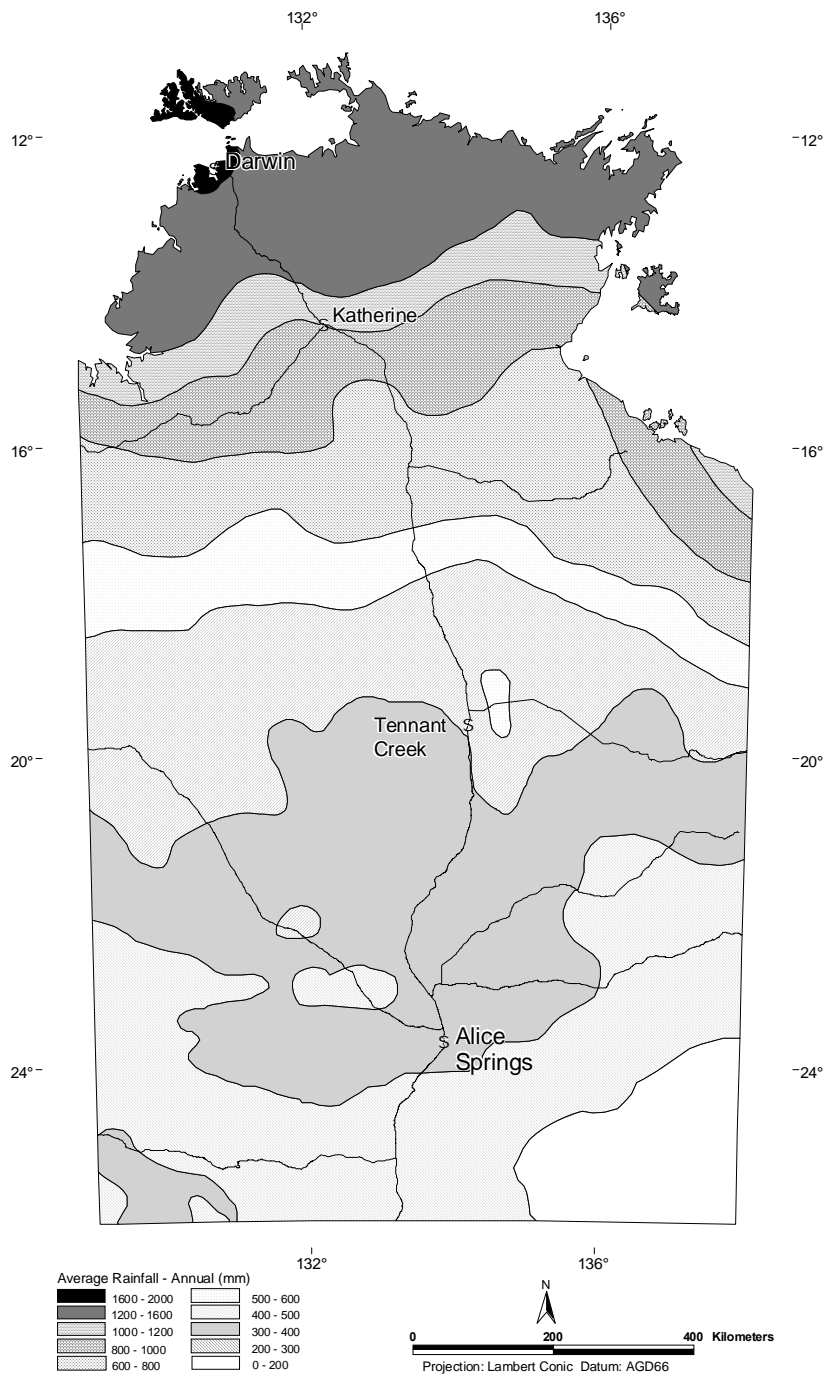


Figure 4. Rainfall isohyet map of the study area.
(adapted from Bureau of Meteorology 2000)

The temperature differences through the year follow the pattern of temperate climates with the main seasons usually described as summer and winter. In the northern part of the area, the relatively regular monsoon influence on rainfall and humidity results in the term 'wet season' being also used for summer time. On average, the hottest month is January and the coldest month is July throughout the study area. There can be large differences between day and night time temperatures; ranges of 20 degrees Centigrade or more are not uncommon. Summer temperatures frequently exceed 40° C, while in the south the winter temperatures are relatively cold, with day time maximums as low as 11° C occurring every few years.

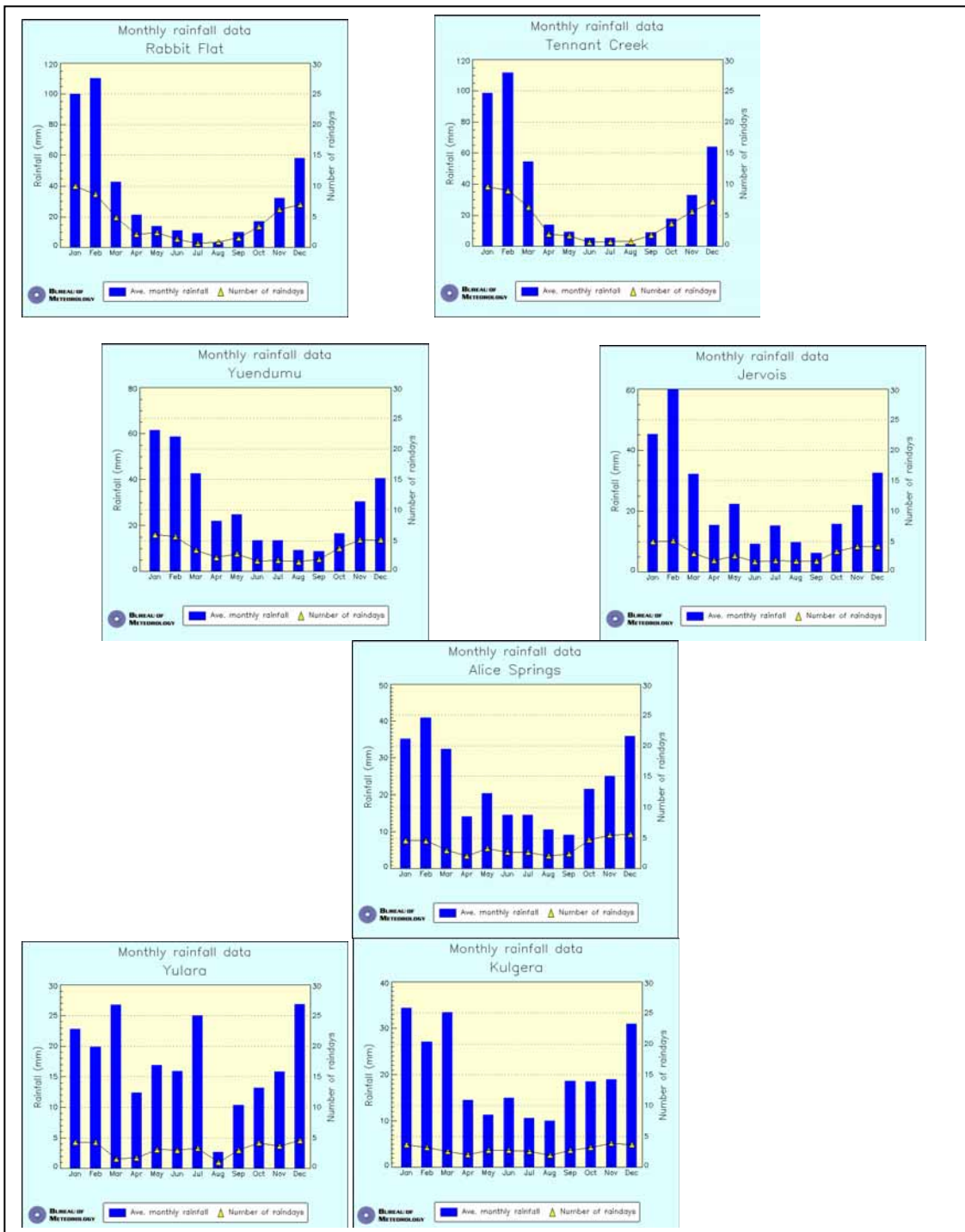


Figure 5. Rainfall seasonality (Jan – Dec) histograms for key localities. Graphs from Bureau of Meteorology 2002, arranged to approximate the spatial distribution of recording stations.

Frosts are common around Alice Springs and southwards, in most years, but are not common further north. The lowest minimum temperature recorded at Alice Springs is -7.5°C which contrasts with $+4.5^{\circ}\text{C}$ at Tennant Creek. Severe frosts are probably more common in the relatively elevated MacDonnell Ranges Bioregion, compared to adjacent bioregions to the south, east and west. The lowest recorded temperature at Kulgera in the south is -4.7°C .

A defining characteristic of the area is the irregularity of its rainfall (Williams 1998a) with the Australian arid zone having high year to year variation in rainfall compared to other parts of the world with similar aridity (Stafford Smith & Morton 1990). The unpredictability of rainfall and tendency to drought has an even greater influence on the natural environment than the low long-term average rainfall. Examination of the annual mean rainfall without considering other climate parameters can be highly misleading. There

are a great many years in which the rainfall is far less than the mean because the long-term mean is greatly influenced by occasional extremely wet years.

The unpredictable or unreliable nature of rainfall can be quantified with the Annual Rainfall Variability Index (Variability = 90th percentile – 10th percentile / median) (Bureau of Meteorology 2000) as illustrated in figure 4. There is a loose gradient of rainfall variability from the north-west to the south-east corner of the arid NT. The majority of the area has either moderate-high (49% of area) or high (44% of area) rainfall variability. The distribution of rainfall is also highly irregular through space as well as through time. The large proportion of annual rainfall that comes from intense events, often thunder storms, means that rainfall often varies greatly between localities in the same region, and even widespread rains may miss some locations.

A number of relatively wet periods of widespread above average rainfall, in one or several years, have occurred since non-Aboriginal records started. Sustained wet periods have occurred in the Alice Springs region in 1876-1878, 1920-1923, 1973-1978 (Griffin & Friedel 1985), in the late 1980s and from the summer of 1999/2000 to the present time. It is unknown whether this pattern is a result of some global atmospheric cycle or a random occurrence (Williams & Calaby 1985). Times of above average rainfall are generally referred to as ‘wet years’ or ‘good seasons’, and may refer to periods of several years. The use of the term season in this context does not refer to an annual weather cycle and can be confusing to people who are unfamiliar with this usage. There have also been a number of sustained periods of several years of below average rainfall. Some of the longer droughts have been associated with the regional elimination of animal species already in decline (Johnson 1999). The two most severe droughts recorded for the Alice Springs region were 1925-38 and 1958-64, with several other shorter periods of very low rainfall also recorded (Griffin & Friedel 1985).

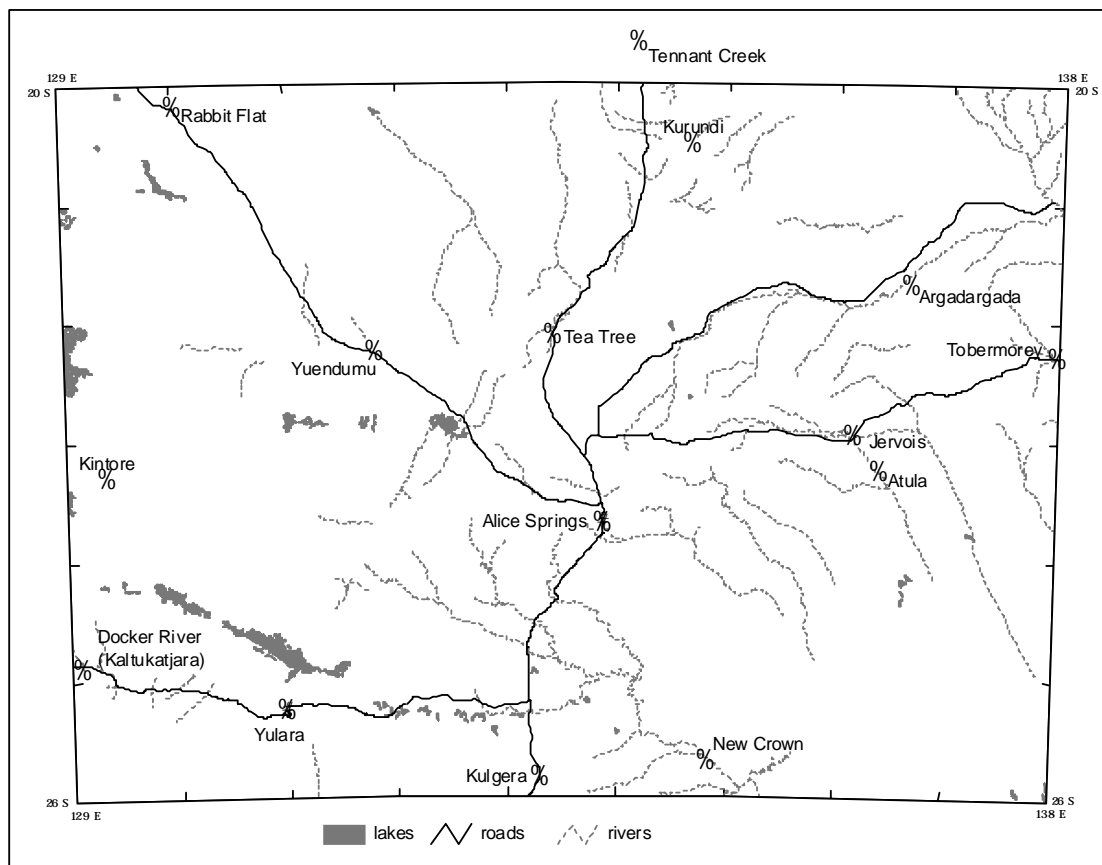


Figure 6. Locations of weather stations referred to in climate tables.

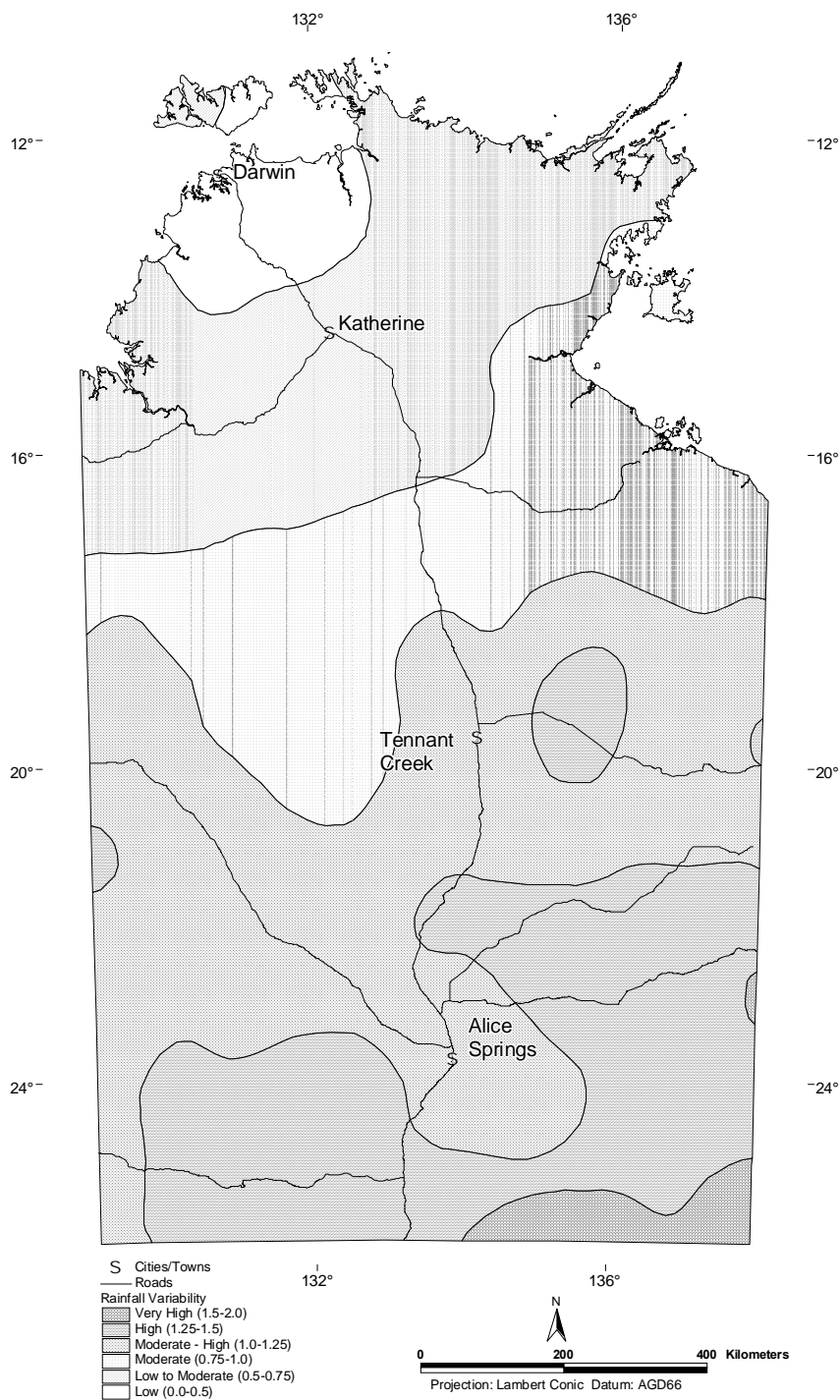


Figure 7. Rainfall variability index map of the study area.
 (adapted from Bureau of Meteorology 2000)

Rainfall Leading Up To and During the Survey

The inventory took place during an unusually wet period. The satellite imagery used to map wetlands was mostly from dates between March and July 2000, following a very widespread wet summer. A second summer of extremely high rainfall occurred again in the summer of 2000-2001, prior to the bulk of the field survey in 2001.

The Alice Springs rainfall for the 36 month period preceding March 2002 was above the mean throughout the study area. Particularly large rainfall events occurred in February 2000, April 2000, December 2000 and March 2001, although not consistently across the study area. The February 2000 event was more

widespread across the region than the April 2000 event. However, the latter was very intense in some areas and resulted in large flows down the Lander River into Lake Surprise (Yinapaka). High rainfall occurred in the Dulcie Ranges, Sandover River floodout and Davenport ranges December 2000. An extreme rainfall event occurred in early March 2001 in the west of the study area, following 2 high rainfall months, resulting in the filling of Lake Mackay, some recharge of Lake Surprise and Lake Lewis and large sheets of water across the lower Tanami Desert, as illustrated in appendix 2. The heaviest rain was well west of the Lake Lewis catchment area and so that lake was not refilled.

The table below indicates the scale and distribution of these high rainfall events leading up to and during the inventory. Some of the monthly rainfall amounts were comprised of a few intense events. The amount of runoff into wetlands is well correlated with rainfall intensity.

Table 5. Monthly rainfall data indicating high rainfall events in 2000 and 2001

All numbers are mm of rain	Feb-00	Apr-00	Dec-00	Jan-01	Feb-01	Mar-01	Annual Mean
Argadargada	-	-	566	32	29	17	336
Alice Springs	131	256	55	176	10	151	321
Atula	75	175	134	123	11	46	276
Docker River	371	96	9	41	31	249	480
Kintore	494	82	59	54	123	-	219
Kulgera	206	75	21	35	1	136	251
Kurundi	384	-	373	62	48	108	340
New Crown	195	45	27	18	15	115	182
Rabbit Flat	191	96	157	245	216	347	440
Tea Tree	342	188	45	15	29	25	289
Tobermorey	178	-	338	40	-	-	254
Yuendumu	301	157	119	121	118	272	350
Yulara	348	96	4	27	0	202	250

1.7 The Policy Context for Wetland Conservation in the Arid NT

This project was carried out in a setting of policies and agreements to protect wetlands; operating at the international, national and Northern Territory levels. These have arisen from increased government recognition of both the benefits that wetlands provide and the serious global decline in wetland area and condition. For lists of benefits obtained from Australian wetlands see McComb & Lake (1998), PWCNT (2000) and Environment Australia (1997). For discussion of global and Australian wetland decline see Mitsch (1998), Wasson *et al.* (1996), and Barson & Williams (1991) who cite an estimated loss of around 50% of Australian wetlands since non-Aboriginal settlement. An overview of the policy context is given here as background to understanding the aims and methods of the inventory and resulting recommendations.

International Context

International cooperation by national governments principally occurs through an international treaty: the *Convention on Wetlands of International Importance*. The treaty is generally known as the Ramsar Convention, after the town of Ramsar in Iran, where it was initially signed in 1971. Australia was among the first signing countries (Australian Nature Conservation Agency information sheet on The Ramsar Convention). International wetlands policies are developed by the Ramsar Convention Bureau, with the Contracting Parties (countries) meeting every three years. Under the Ramsar Convention, a 'List of Wetlands of International Importance' is maintained. The Wetlands of International Importance are also known as Ramsar sites and must meet established criteria. The contracting parties to the Ramsar Convention are required to:

- nominate sites to the List of Wetlands of International Importance;
- promote the wise use of all wetlands in their territory;
- promote the training of wetland managers;
- consult with each other on wetlands issues such as migratory birds;
- create and manage wetland reserves (Australian Nature Conservation Agency information sheet on The Ramsar Convention).

Currently there are no Ramsar sites identified in the arid NT.

Australia is also a signatory to several international agreements specifically about migratory shorebirds: The Japan-Australia Migratory Bird Agreement (JAMBA), the China-Australia Migratory Bird Agreement (CAMBA) and the Japan-China Migratory Bird Agreement. These involve an agreement by the Australian Commonwealth Government to 'preserve and enhance the habitats used by migratory birds' (Environment Australia information sheet on Safe Landings for Shorebirds – Migratory Bird Conservation).

National Context

At the national level the *Wetlands Policy of the Commonwealth Government of Australia* (Environment Australia 1997) and the *Implementation Plan for the Wetlands Policy of the Commonwealth Government of Australia* (Environment Australia 1999) provide a framework for coordinated conservation of Australian wetlands. Implementation of the Commonwealth policy is primarily through the National Wetlands Program and through the Natural Heritage Trust Partnership Agreements between the Commonwealth and State/Territory Governments (Environment Australia 1999). The National Wetlands Program is administered by the Commonwealth Government department of environment, called Environment Australia (formerly the Australian Nature Conservation Agency). The Wetlands Policy recognises that various other Commonwealth policies and legislation relate to wetlands, such as the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth 1994). The Commonwealth Government role in wetland protection outside of Commonwealth lands is also influenced by the World Heritage Convention and the Australian Heritage Commission Act 1975 (Michaelis & O'Brien 1988). However, there are currently no wetlands in the arid NT that are listed as world heritage areas. Neither are there any in the Register of the National Estate, which is maintained by

the Commonwealth Government under the Australian Heritage Commission Act, and includes wetlands elsewhere in Australia. Australia is also party to the International Convention on Biological Diversity (internet site of ASL – the Australian Wetland Forum).

The inventory of the arid NT, which is the subject of this report, is part of the National Wetlands Program and has been carried out with the assistance of money from the Natural Heritage Trust. The inventory addresses one of the main priorities of the National Wetlands Program – ‘supporting the surveying and monitoring of wetlands’. An element of the national policy is the maintenance of *A Directory of Important Wetlands in Australia* which is currently in its third edition (Environment Australia 2001). Supporting the compilation of further editions is part of Strategy 4 of the Commonwealth Policy (4.1 Working in partnership with State/Territory Governments) and a requirement of the Natural Heritage Trust funding of the inventory is that sites be identified for inclusion in *A Directory of Important Wetlands in Australia*.

The inventory also contributes to other aspects of implementing the Commonwealth policy, including promoting greater community awareness, wise use of wetlands, research into weeds and other threatening processes and promoting wetlands conservation and management. The information generated on the types and distribution of wetlands will be valuable to Water-watch, which is funded under the National Wetlands Program to promote community awareness of wetlands and involvement in monitoring and management.

The Australian and New Zealand Environment and Conservation Council (ANZECC) is made up of the environment Ministers of the State, Territory and Commonwealth governments. It is a forum in which the State/Territory and Commonwealth governments cooperate in developing policies and actions concerning the natural environment. A working group of wetlands experts from each of the governments is convened by Environment Australia under the auspices of ANZECC; called the ANZECC Wetlands and Migratory Shorebirds Taskforce.

In 2001, the Commonwealth, in conjunction with some of the States, published ‘National Objectives and Targets for Biodiversity and Conservation 2001–2005’. This included a goal of all jurisdictions identifying wetlands of national and international importance and a goal of ‘By 2005, all jurisdictions have effective legislation and management plans in place to protect wetlands of national significance’.

The National Wetlands Research and Development Program is conducted by the Land and Water Resources Research and Development Corporation (LWRRDC) (Bunn & Schofield 1997). LWRRDC is a Commonwealth Government body that identifies and funds research aimed at increasing the sustainability of national land, water and vegetation use (Boulton & Brock 1999).

Various non-government organisations in Australia exist for wetland conservation or include it in their aims. Many such organisations seek to influence government wetland policy. A list of such organisations is given in appendix 9 to facilitate further cooperation in future wetlands work in the arid NT.

Readers are directed to the following papers and to the list of organisations in appendix 9 for more information on international, national and state/territory agreements, legislation and policy concerning wetlands: *Australian wetland policies, research and management* (Jensen 1997); *Wetland Inventory – towards a unified approach* (Barson & William 1991); *Preservation of Australia’s Wetlands: A Commonwealth Approach* (Michaelis & O’Brien 1988); and *Waterbirds as the flagship for the conservation of arid zone wetlands?* (Kingsford & Halse 1998).

Northern Territory Context

At the NT level, wetland related actions of the Northern Territory Government are guided by: *A Strategy for Conservation of the Biological Diversity of Wetlands in the Northern Territory of Australia* (PWCNT 2000). This project directly addresses three of the objectives of the strategy:

- 2) To improve knowledge of Northern Territory wetlands and the biological diversity they support.
- 3) To identify wetland sites of special conservation value.
- 4) To identify and monitor significant threats to wetland sites of special conservation values.

The inventory also provides a basis for another of the strategy objectives:

- 1) To inform the public and involve the community in the conservation and sustainable management of wetlands.

There are numerous actions listed under the NT strategy and the inventory of the arid NT is consistent with many of them. It has directly carried out one of the actions listed under objective 2: to 'give particular emphasis to inventory of arid zone wetlands'.

The Northern Territory Parks Masterplan was released by the NT Government in 1997 with the aim of developing the system of conservation reserves, including protection of rare and endangered flora and fauna. The parks masterplan also expands on the aim of developing a reserve system that is representative of the range of natural environments, consistent with the *National Strategy for the Conservation of Australia's Biological Diversity* (Commonwealth Government 1996) and *A Conservation Strategy for the Northern Territory* (NTG 1994). It also recognises the importance of conserving species and their environments outside of reserves. A complete revision of the masterplan is due for completion in 2005.

1.8 Overview of Pre-existing Knowledge and the Need for an Inventory

Prior to this study there was scant documentation of the distribution and hydrological and ecological functioning of wetlands of the arid NT compared to many parts of the country. This was due mainly to the remoteness and distance from major population centres, but also to a perception that the wetlands may be of limited conservation value. The lack of knowledge of wetlands in the Australian arid zone and the effects of episodic events were described by the Australian Wetlands Forum as a major information gap (internet site for ASL). A summary of the information for the arid NT prior to this inventory is given here; particularly information concerning the distribution, nature and significance of wetlands.

The Horn Scientific Expedition to central Australia in 1894 was the earliest dedicated biological survey in the arid NT and includes accounts of some wetlands of the George Gill Range and the Finke River system, including some of the fishes and aquatic invertebrates (Davis 1996).

Approximately two thirds of the arid NT was surveyed and mapped by CSIRO for landsystems in the 1950s and early 60s (Perry 1962). The map and associated report provide useful background information on the soils, climate and vegetation of the region, but not a great deal about individual wetlands.

The CSIRO Division of Water Resources produced the first Australia wide classification and description of wetlands: *Aspects of Australian Wetlands* (Paijmans *et al.* 1985). That report described wetland types and discussed broad aspects of the climate, hydrology, geomorphology and vegetation of wetlands. However, it had very little information specifically about the arid NT. The work reported was associated with a proposed national wetlands survey which never took place.

The first substantial review of wetlands in the Northern Territory was by Finlayson *et al.* (1988) in the NT chapter of *The Conservation of Australian Wetlands* (McComb & Lake 1988). However, it contained only minimal information about wetlands of the arid NT, due to a lack of published information, and stated that a concerted effort was required to address the dearth of knowledge.

The introduction to the Northern Territory in *A Directory of Important Wetlands in Australia* (Usbeck & James 1993) and the associated descriptions of 4 important wetlands in the arid NT, collated some of the known wetland information but did not systematically review wetlands of the area. The original introduction to the NT in the first edition was by Fleming (1993a) with wetland descriptions prepared by Jaensch (1993). The second edition (Australian Nature Conservation Agency 1996) included an updated introduction for the Northern Territory by Whitehead and Chatto (1996) and updated information for one arid NT site. For the third edition (Environment Australia 2001), the Parks and Wildlife Commission of the Northern Territory provided corrections to the descriptions of the arid NT sites (Duguid & McNellie 2000).

The 1995 report on *Refugia for biological diversity in arid and semi-arid Australia* (Morton *et al.* 1995) includes limited information for only a few other important wetlands.

The only other wetland review covering the Northern Territory was the *Overview of the Conservation Status of Wetlands of the Northern Territory* by Storrs and Finlayson (1997). This included only a small amount of extra information on arid NT wetlands compared to Finlayson *et al.* (1988) and Paijmans *et al.* (1985). It does provide a more systematic review of the available information and the gaps that need to be filled and highlights the importance of inventory as ‘a prerequisite for holistic conservation management’ (Storrs & Finlayson 1997, p.1). It also includes useful summaries of wetland values for each NT bioregion, but unfortunately reproduces several geographical errors from earlier publications. Several such errors in description of locations and their relationship to bioregions have arisen from reviews being conducted without local knowledge.

A review of wetland management issues in Western Australian and central Australia (Davis & Froend 1998) includes a very brief summary of waterholes associated with mountain ranges. The report was conducted in association with the Land and Water Resources Research and Development Corporation (LWRRDC) and includes a call for further research and monitoring.

The portion of the NT directly to the north of the arid NT is variously referred to as semi-arid, the semi-humid tropics, and as the central area of the NT. Its wetland values are relatively well known compared to the arid NT following a series of studies in the 1990s, which had a particular focus on waterbirds (Fleming 1993b, Jaensch 1994, Jaensch & Bellchambers 1997). The studies of wetlands in the semi-arid NT are useful for assessing the significance of arid NT wetlands for wetland birds.

In recent decades there has been substantial wetlands research in various parts of arid Australia, outside of the Northern Territory. These include surveys of the floodplains of the Murray Darling System and the Cooper Creek – Coongie Lakes system (for example Puckridge *et al.* 2001). Various publications have generally raised awareness of arid Australian wetlands in the scientific community, including Williams (1999). Wetlands research in other parts of the Australian arid zone provides a reference against which to compare the wetlands of the arid NT and provides some insights into their ecological processes.

There was very little systematic mapping of wetlands of the study area prior to this study. Paijmans *et al.* (1985) derived density maps of very broad wetland types across Australia. They derived these from unpublished wetlands maps which they created using the mapping of waterbodies on the 1:250,000 scale topographic maps. Their density maps provided a broad indication of the national distribution of the broad wetland types but were quite uninformative at the more detailed scale of the arid NT. The underlying waterbodies mapping is now available as digital GIS polygon data (AUSLIG 1994), however it does not include attributes for wetland type and some types are very poorly mapped or missed altogether. Further details of pre-existing wetland mapping are given in the mapping section of this report.

There is growing evidence that arid Australian wetlands have a highly diverse and distinctive fauna with freshwater wetlands having as high or higher biodiversity than comparable temperate wetlands (Williams 1999). However, prior to this study, information about the biota of arid NT wetlands was mostly fragmented and relatively inaccessible. Pre-existing information about plants and animals is summarised and referenced in the sections reviewing wetland plants, birds and invertebrates. Most of the published scientific literature about the biota of arid Australian wetlands is from research outside the arid NT. It provides a useful basis for comparison but is not a substitute for direct investigation of arid NT wetlands. More consistent information was and still is required about the biota, in order to make meaningful assessments of the conservation significance of particular wetland areas. A useful national overview of wetland biota is included in the Commonwealth Government report summarising aspects of Australian biodiversity (Mummery & Hardy 1994).

There is survey data for various wetlands in conservation reserves in the Alice Springs region, consisting of information on vegetation species, structure, soils and landform. These data were collected during the process of biophysical mapping and survey of parks by Brenda Pitts and others.

A review of arid NT plants species and sites of botanical significance was completed in 2000 which included lists of rare and threatened plants in several broad wetland environments (White *et al.* 2000a), and also included lists of waterholes of known botanical significance (White *et al.* 2000b).

Over the past two decades, the NT Government and others have conducted biological surveys to a number of areas that have included wetland environments. Most of these surveys were reported only in

unpublished, internal reports, with a few being released as technical reports. Also, resource appraisal reports were written for many pastoral stations as part of the process of granting perpetual pastoral leases.

There are various sources of information about water resources. A database of stream flow gauging and water quality is maintained by the Natural Resources branch of the NT Government Department of Infrastructure, Planning and Environment.

The hydrogeology of various areas in the arid NT have been well studied for water resource assessment. Some of these studies include information about the role of groundwater in the hydrology of natural surface waters, particularly salt lakes and information about springs: water volume, quality and longevity. Examples of wetland locations presented in hydrogeological reports and maps are given in the mapping chapter of this report.

There have also been studies of surface water resources for many pastoral properties in the Alice Springs district. These document both natural and artificial surface waters, with an emphasis on waters used for domestic or commercial purposes rather than natural biological values (G. Ride pers. comm.).

The lack of information on arid NT wetlands must be seen in the context of global wetland decline, in order to understand the need for an inventory. General awareness of wetland conservation issues was boosted by a global campaign launched in 1985 by the International Union for the Conservation of Nature (IUCN) and World Wildlife Fund (WWF) (McComb & Lake 1988). However, despite increased recognition of the benefits of wetland conservation, wetlands still have negative associations for many people. For example, they may be viewed as areas of unproductive land that harbour pests and diseases. There are also many human driven processes that threaten wetland values in Australia.

This inventory of arid NT wetlands is part of national and international efforts to document wetlands and threatening processes so as to provide a basis for informed decisions about land use and management. Although the most well known wetlands and associated conservation problems have generally been in temperate areas and the humid tropics, wetlands in arid areas are also at risk (Williams 1999). Also, conservation in the arid NT has been somewhat handicapped by the myth that its ecosystems are in an undisturbed natural state. This is partly due to the low levels of land clearing and urban and industrial development. However, the impacts of introduced plants and animals and altered land uses and fire regimes should not be underestimated.



2. Overview of Inventory & Survey Methods

Scope

This section describes the methods used to conduct the inventory, including an overview of the survey techniques. Techniques used to survey birds, plants and fishes are discussed further in chapters on each group. The mapping methodology is presented in chapter 13 together with a review of pre-existing mapping and results of new mapping.

2.1 Background: Required Elements of a Wetlands Inventory

There is a growing body of literature on techniques and requirements for regional wetlands inventory, in an Australian context. Reviews of the Australian situation, including past inventories in each state and territory, were written by: Barson and Williams (1991); Pressey and Adam (1995); and Spiers and Finlayson (1999).

Techniques for enhanced wetland inventory and monitoring (Finlayson and Spiers 1999) is a report which focused on Australian issues, and was funded under the National Wetlands Program by the Environment Australia Biodiversity Group. In particular, the report includes proposed protocols for an Australian national wetland inventory (Finlayson 1999). The report also includes a section assessing the extent of wetland inventory data in Australia at that time (Spiers & Finlayson 1999). In that section the authors join others in advocating a national approach to wetland inventory. Whilst there is still no nationally endorsed approach, this inventory of the arid NT has taken account of the recommended protocols of Finlayson (1999) as advised by Roger Jaensch (Jaensch 2000).

Finlayson and Spiers (1999) present the following internationally agreed definition of wetland inventory:

‘Inventory is the collection and/or collation of core information for wetland management, including the provision of an information base for specific assessment and monitoring activities’ (Finlayson & Spiers 1999, p.141).

Two fundamental aspects of wetland inventory are:

- mapping, which Finlayson (1999, p.120) calls ‘delineating wetland habitats’; and
- describing ecological character.

Both of these generally involve creating or applying a classification of wetland types, for use in summarising ecological character and as a basis for presenting the area and distribution of types in mapped and tabular form. The classification derived for the arid NT and the wetland attributes incorporated into it are reported in a separate chapter of this report.

Key aspects of wetland character are size, the pattern of inundation through space and time, the salinity and the vegetation structure, the presence of characteristic and rare or threatened species and general use by wetland animals.

Several authors stress the importance of recording ‘primary data’ (direct observations and measurements) as opposed to derived, interpreted or classified data (Barson & Williams 1991; Blackman *et al.* 1992). In our experience, it is also important to provide room on survey forms for free format descriptions of wetland features to incorporate unanticipated types of observation and local testimony.

Biodiversity assessment is not an essential part of all wetland inventory (Jaensch 2000) and may be better described as wetland assessment (Finlayson 1999). However, some biodiversity survey was essential in this inventory of the arid NT, given the general lack of knowledge of the biota of arid NT wetlands, the requirement to assess their conservation significance and the expense of reaching sites for ground survey.

In the original funding proposal for this wetlands inventory, it was indicated that the survey methodology used to inventory the semi-humid tropics of the NT (Jaensch 1994; Jaensch & Bellchambers 1997) would be adopted for the inventory of the arid NT. However, this was not possible due to the lesser importance of waterbirds in the arid as opposed to semi-humid portions of the NT and the importance of incorporating other aspects of wetland inventory.

2.2 Consultations with Experts and Community

Consultations were important in the following areas of the project: refining methods; creating a preliminary list of wetland types; identifying pre-existing information on important wetlands and survey priorities; arranging access to field sites; and obtaining information about individual wetlands from local knowledge. A list of people consulted is included in appendix 4.

Early in the project, two workshops were held in 1999 to obtain input from local scientists and others with field experience of arid NT wetlands. The first workshop was with Parks and Wildlife staff (8 Nov 1999) and the second was with the broader scientific and land management community of Alice Springs (Rangelands Society Seminar Series, 15 Dec 1999).

Roger Jaensch of Wetlands International assisted the project team in developing the methodology. An initial consultancy of one week (May 2000) involved intensive office based discussions of the issues and options and brief field excursions with other members of the project team. A comprehensive report was prepared by the consultant based on these activities (Jaensch 2000). A second one week consultancy (July 2000) consisted of an aerial reconnaissance flight and a four day field trip to a diverse array of wetland types, to further develop both the working classification and the ground survey methods.

General discussions of the aims and methods of the project were held with the Central Land Council and the Centralian Land Management Association (CLMA - a Landcare group comprised of pastoralists). These two organisations represent the majority of landholders. Consultations were held with owners and or managers of individual properties prior to and during survey work. A project information sheet was distributed during consultations with landholders and others. It is appended to this report as appendix 3.

A summary report was prepared of wetlands surveyed on each pastoral property visited, and was sent to the station managers. Pictorial reports were prepared and sent to traditional owners of areas surveyed on Aboriginal Land Trusts.

2.3 Field Survey Methods

The broad aims of the ground survey component of the inventory were:

- collect sufficient information (and photographs) to define and describe wetland types;
- allocate individual wetlands to preliminary (apriori) wetland types;
- record data relevant to assessing conservation significance including the presence of rare or threatened species, hydrological regime, and waterbird abundance and breeding;
- identify threats to wetland conservation;
- test the accuracy of water body mapping on the 1:250,000 topographic map series, including floodouts and land subject to inundation;
- identify indicator plants of use for identifying wetlands and the nature of their inundation history;
- collect frozen specimens of fishes for genetic research by the South Australian Museum and Deakin University; and
- add to knowledge of the distribution and habitat preferences of plants, fishes and wetland birds.

Field testing the mapping of wetlands on the 1:250,000 topographic maps involved recording erroneous mapping of an area as a wetland, recording an area as a wetland which was not mapped and recording broad wetland type.

The survey methodology adopted for the arid NT inventory was flexible in terms of the size of a site and the detail in which various wetland attributes were recorded. This was necessary in order to meet the broad objectives of a reconnaissance scale inventory, combined with some detailed biological survey necessary to describe the range of wetland types.

The detail with which a site was surveyed was influenced by: the state of inundation and vegetation response; a preliminary assessment of conservation importance; and available time. Where time permitted, primary information was recorded about the wetland, rather than allocation of wetland features to categories. Even where attributes were estimated and not measured, such as maximum depth observed and potential maximum water depth, the estimated values were recorded, often as a range, rather than categories. In order to cover sufficient area during the ground survey, some sites were very rapidly assessed; sometimes without getting out of the vehicle. Such sites were called 'ultra-rapid' and served the purpose of documenting the abundance and distribution of wetland types and attributing and testing the mapping of waterbodies on 1:250,000 topographic maps.

Aerial photography was used in the field for navigation and site selection in a small proportion of areas visited. The large areas covered in each field trip and limited resources did not permit consistent use of existing aerial photography for either survey or mapping. Any more detailed survey work subsequent to this inventory would benefit greatly from the use of aerial photographs. A scale of 1:50,000 or more detailed is recommended. Plots of recent satellite imagery (ETM+) were used as a navigation aid where available (roughly half the survey area).

The survey of plants and animals was less systematic than in studies focused primarily on ecology or vegetation mapping. A compromise was necessary between detailed biological survey and broader wetland inventory. The emphasis was on recording the presence of species at wetlands and in distinctive sub-habitats (zones) within wetlands (plants only). Quantitative sampling and abundance estimates were of secondary importance. Estimates of abundance were made for birds (numbers) and plants (modified Braun-Blanquette cover-abundance classes) at a sub-set of sites, and only opportunistic sampling of fish and aquatic invertebrates was undertaken. The size of sampling areas was not standardised. This allowed maximum flexibility in obtaining comprehensive species lists in the least amount of time. There is a large variation in spatial arrangement and patch size of sub-habitats (zones) within wetlands and systematic but representative sampling would require multiple small fixed area plots in each zone and/or a gradient-transect method. The use of such methods would have conflicted with the need to inspect a large number of sites. For the same reason, plot locations were not randomised within wetlands and neither was the selection of wetlands to be surveyed.

Survey Site Selection

The aim was to survey a representative sample of wetlands across the range of wetland types as well as across the geographic range of the study area. A formal stratification was not undertaken. Survey trips were planned according to particular geographic areas on the basis of existing knowledge about wetland values and accessibility. Land tenure was a defacto stratification layer, in that wetlands on pastoral leases, national parks and Crown Land could generally be more easily visited than those on Aboriginal controlled land. Gaining permission to visit Aboriginal Land Trusts is often time consuming due to cultural and language differences and the fact that often many different people must be consulted. Both the IBRA bioregions (Thackway & Cresswell 1995) and national drainage basins were considered in trying to make the sampling representative.

Information about potential survey sites and areas was obtained from existing mapping of wetlands, various general biological survey reports, satellite imagery, some limited aerial survey and advice from local scientists, particularly Peter Latz. Also, existing data about the distribution and wetland affinities of plants and animals were collated and records of vascular plants, birds and fish were inspected with a geographic information system. Based on the collated information survey trip itineraries were developed.

Survey routes were chosen so that a large number of wetlands could be briefly inspected and assessed against a preliminary classification of wetland types, in addition to more thoroughly surveyed sites.

Landholders were a valuable source of extra information about the occurrence and nature of wetlands and access routes. Additional sites were often selected during the field trips based on discussions with landholders.

Survey Sites and Individual Wetlands

The term 'site' is not necessarily equivalent to a wetland. In our survey, a site was the part of the wetland observed and for which information was recorded on a site sheet. The size of the site was variable and only sometimes did it incorporate an entire 'wetland'. Where possible, sites were located so as to be representative of the wetland being surveyed and information was recorded regarding the entire wetland as well as for sub-habitats within it. Some large and complex wetlands were surveyed with more than one site. Similarly, at large complex wetlands some parts were often surveyed more thoroughly than others.

Site location was not necessarily equivalent to the centre of the wetland (centroid). The coordinates of a point within or adjacent to the survey area were recorded using a global positioning system device (GPS). Where possible the GPS fix was taken in the centre of the area surveyed. The relative position of the coordinates with respect to the surveyed area and the whole wetland were described. The general location of the site was described with respect to features mapped on the 1:250,000 scale topographic map and included the property name.

Attributes Surveyed

The following core data was collected at all ground survey sites:

- date;
- observer(s);
- site code (combination of letters indicating the property name or survey area and the sequential site number for that property or area);
- sample type (rapid/standard);
- map sheet name (1:250k);
- wetland name(s) and origins of name (m=map, s=name created during survey, l=local);
- position coordinates, datum, method, accuracy and relative position with respect to the wetland (GPS/Map, +/- x metres; for some rapid sites the site number was marked on a topographic map, with coordinates determined later);
- location description (property name, distance and direction from a named feature on 1:250,000 topographic map);
- whether or not mapped on 1:250,000 topo map (Y / N);
- adequacy of mapping (comment);
- general description (uniformity, patterning, vegetation structure and key plants if not recorded elsewhere, and information from local or other knowledge of the wetland);
- wetland type(s) from working (apriori) classification (proportion of dominant and other types);

The following attributes were described at most ground survey sites:

- comments on access;
- wetland size (estimated dimensions);
- observation method (one or more of ground, boat, hill, aircraft, drive by);
- proportion of wetland inundated;
- current depth (estimated or measured);
- maximum depth (estimated or measured);
- water colour (e.g. clear / yellow brown / milky brown / other);
- water turbidity (estimated not measured: clear / low / medium / high turbidity);
- flow speed (still / slow / fast);
- water conductivity and pH (where a sample was taken for laboratory testing this was noted);
- algal growths in water (comment);
- water regime (permanent / long-term / temporary ; other information on inundation events/frequency and information sources);

- catchment / hydrology comments;
- earthworks or other mechanical modifications (description);
- presence of fish (seen / not seen / listed);
- presence of aquatic invertebrates (seen / not seen / listed; no. of samples);
- presence of waterbirds (seen / not seen / listed);
- detail of plant list (whether or not comprehensive: full / partial);
- adjacent and nearby landforms and vegetation types (general description);
- photographs (photo number/description);
- time spent (estimated person hours);
- presence and extent of visible salting on surface;
- thickness of salt crust if extensive;
- ground surface cover types (% bare ground, % loose rock, % bare rock);
- surface soil description (colour, estimated texture, cracking, thickness of inorganic crust); or
- rapid assessment of disturbance factors (weeds, rabbits, horses/donkey, camels, cattle; impact scored as 1 – 5);
- vegetation condition (shrubs & trees stressed, forbs stressed, fresh growth, no stress, seedlings present, drowned dead shrubs);
- dominant and key plants (e.g. Redgum, Coolabah, Lignum, Nardoo, Couch; even if not dominant)
- vegetation structure (brief description);
- lists/comments regarding species seen: plants, fish, waterbirds, other birds, invertebrates, frogs;
- sketch map (shape of wetland, arrangement of sub-habitats, dimensions, and position of adjacent landforms).

At some sites, more detailed floristic survey was conducted of the vegetation in one or more zones of the wetland. At these sites soils were also surveyed in more detail. Soil and vegetation sampling are described in more detail in the chapter on plants, but included:

- compiling a plant species list for the wetland as a whole or for particular zones (sub-habitats);
- where time permitted, cover and abundance were estimated for each species in one or more zones (sub-habitats);
- soils were described in moderate detail from a soil pit in at least one zone where full plant cover and abundance were recorded (soil texture, pH, stoniness, mottling, and horizon depths);
- soil salinity was determined in the laboratory (as conductivity) for all horizons sampled from pits.

At some sites birds were systematically observed and counted. Details of methods are described in the chapter on wetland birds.

At some sites fish and aquatic invertebrates were sampled. This was done with a variety of methods as described in the chapter on fishes. The sampling was opportunistic and did not involve systematic sampling of different aquatic environments within the wetland.

The field survey data proformas are presented as Appendix 2.

Aerial survey

Aerial survey was used for general reconnaissance, for rapid site assessment, to conduct bird counts of selected wetlands and to obtain photographs to assist with interpreting and promoting wetlands. Counting numbers of waterbirds was not a core activity of the inventory and was restricted by time and budget constraints. There was only two days of aerial survey for bird counting and one wetland reconnaissance flight over parts of the Finke and MacDonnell Ranges bioregions. However, wetland occurrence and broad wetland type data were collected during an extensive aerial camel survey that was conducted in 2001, concurrent with the wetland inventory.



3. Origins of Central Australian Wetlands: Hydrology, Geology, Geomorphology and Past Climates

Scope

The ecological functioning of wetlands is strongly influenced by broader landscape processes. A general understanding of the hydrological systems and geomorphology of the arid NT provides a foundation for understanding the wetlands. Here, a brief overview is given of: the sources of water in those wetlands; the geological origins of the present landscape; knowledge of past climates; and ongoing geomorphic change. The aim is to illustrate the broad processes and time scales involved as a background to understanding the present day distribution and function of arid NT wetlands and their biota. This section also introduces terminology used elsewhere in the report.

3.1 Hydrological Processes in Arid NT Wetlands

Hydrological processes have a fundamental influence on both the existence and ecological function of wetlands. Hydrology is the study of the distribution and movement of water in the natural environment and incorporates the ways in which water reaches a wetland and the frequency, duration and depth of inundation. The movement and retention of water are strongly determined by the shape of the land surface (landform) and by the substrate (soils and rocks). Thus, in the words of Barson and Williams (1991, p.9):

‘Wetlands are the surface expression of interactions between regional hydrology and geomorphology at a particular position in the landscape’.

The following section provides an introduction to hydrological aspects of arid NT wetlands. Readers seeking a deeper understanding are recommended to commence with the following references. Paijmans *et al.* (1985) provide a general overview of the hydrological cycle as it influences wetlands. Hatton and Evans (1997) summarise aspects of groundwater hydrology and its influence on ecosystems including wetlands. The hydrogeology of the Amadeus Basin is effectively summarised by Jacobson (1996), including the main aquifers, their recharge and the rates at which water moves within them. Various other hydrological sources are cited through the report. The following summary of wetland hydrology was influenced by the sources above but also by information from hydrogeologists based in Alice Springs (Graham Ride, Robert Read and Anthony Knapton pers. comm.).

Sources of Water in Wetlands

Pajmans *et al.* (1985) divide the ways in which precipitation supplies wetlands into four systems, These are described below with some additional interpretation.

Regional runoff: reaches the wetland by in-channel flow from upstream surface runoff. Channel flows may also include some water from groundwater discharge into the channel. Channels may discharge directly into a wetland basin or by side (tributary) channels or by over-bank flow. Under our definition of a wetland, channels themselves and waterholes along them are also wetlands.

Local runoff: is precipitation in the vicinity of the wetland, including directly over it, delivered by local stream channels and also sheet-flow.

Regional ground water flow: supplies wetlands in the discharge zones of major groundwater basins such as: the Great Artesian. There are several large hydrological basins in the arid NT, as well as smaller ones, including both confined and unconfined aquifer systems. Boulton and Brock (1999) distinguish 'effluent' streams, those being charged with water entering the channel from ground water, and 'influent' streams, which are those which are losing water into the ground. A single river may cross a series of groundwater discharge and recharge zones, such as the Finke River (G. Ride pers. comm.). Many salt lakes are regional discharge areas (Wischusen 1998) as well as receiving surface water from regional and local runoff.

Local groundwater flow: describes areas that have 'have recharge and discharge areas on adjacent minor topographic highs and lows, [such as] sand dune ridges and swales'. Groundwater flow paths range from 'a few metres to about a kilometre, with response time no more than a year or two' (Pajmans *et al.* 1985, p.6). In the arid NT it is likely that after major rain events shallow ground water systems also operate between salt lakes and surrounding sandplains and probably over distances greater than 1km. Also, we have documented small-scale wetlands in the arid NT that are dominated by local aquifers in relatively large mountain ranges, not just minor topographic highs.

All four of these supply systems operate in the arid NT, although the distinction between them is not always clear. Their relative importance is discussed for wetland types and for some individual wetlands in the following chapters. Each system can also be a component of water loss from wetlands. However, the main cause of water loss is evaporation (including transpiration by plants). Because annual evaporation is very high across the arid NT, permanent water bodies are rare and nearly all of 'those that do occur depend on groundwater flow' (Pajmans *et al.* 1985, p.4).

Groundwater Systems and Terminology

Groundwater includes water in saturated soil and unconsolidated sediments as well as rock aquifers. Rock aquifers store and transmit water in a variety of ways including general porosity, gaps created by fracturing and gaps from chemical reactions such as in calcareous rocks (e.g. limestone caves). The term water-table can apply to various groundwater types.

Aquifer discharge at or near the earth's surface has various expressions; from massive salt lakes to tiny seepages supporting relict fern species. Salt lakes typically have a zone of saturated hypersaline soil (brine pool) below a crust. Places where aquifer discharge creates surface water flows are typically called springs. Where the discharge rate is too low to create running water, terms such as seepage, soak or 'blind spring' may apply. The substrate also influences whether or not there is running water. Even small discharge rates onto rock or clay can produce running water. In sand, coarse gravel and cobbled ground, such as many river beds, a much greater rate of discharge is required to create running water. The flow rate of many springs varies markedly through time, depending on the magnitude of recharge events and the time between them. Some springs dwindle to a seepage or may cease altogether between recharge events. In cases where aquifer discharge rises through a soil layer, transpiration and direct evaporation from the ground will effect the rate of surface water flow. Accordingly, ambient temperatures and the successional state of vegetation can also influence surface flows at such springs.

Some springs are essentially hidden because they discharge into permanent waterholes. Other aquifer discharge may be hidden by the depth of 'soil' above. A fascinating example of this is Palm Valley, where sub-surface aquifer discharge sustains the relict Palm Valley Palm trees in the drainage lines. This is undoubtedly a groundwater dependent ecosystem as defined by Hatton and Evans (1997), yet its status as a wetland is ambiguous. The palm trees gain access to groundwater where the drainage lines are

incised into overlying rock strata, but their presence is not obviously dependent on inundation or surface soil saturation.

Some aquifer discharge is directly into river sands. At Running Waters, on the Finke River, the massive rate of discharge produces a large permanent running waterhole, hundreds of metres long. At Ettenia Spring a much smaller discharge produces a short shallow running stream within a sandy creek bed. It is likely that there are various other examples that do not produce any surface flow, being 'hidden' by the depth of sand, gravel or cobbles above.

Although the rivers of the arid NT are dry most of the time, many have water 'flowing' under the sand in the hyporheic zone. Some waterholes are sustained by this hyporheic flow and are 'windows' on the riverine watertable. The water in the hyporheic zone includes a mixture of surface water from runoff that has drained into the sand and water from aquifer discharge. The magnitude of hyporheic flow in arid NT rivers is largely undocumented but it is possible that hyporheic flow may be a significant source of recharge for some aquifers (Graham Ride pers. comm.).

Graham Ride (pers. comm.) reports that the salinity of some long-term/permanent waterholes can vary over time, being generally freshest after river flows, and typically becoming saltier due to a combination of evaporation and saline ground water discharge. He also has evidence that the salinity of discharging ground water can change through time. An example of saline discharge from our work is a change in conductivity in the Finke River from 2700us/cm near Idracowra Homestead to over 4000 us/cm downstream near Horseshoe Bend Homestead. Conductivity was measured in residual (post-flood) flow and the increase in salts corresponds to the confluence of the Finke River and the Karinga Creek Paleodrainage System.

Most of the examples above are from confined aquifers, where a water-bearing rock strata is overlain by relatively impervious strata. The sites of discharge or recharge are where the aquifer rocks are exposed at or near the earth's surface and are typically quite localised. Unconfined aquifers also influence wetlands in the arid NT. Unconfined aquifers include unconfined rock strata, unconsolidated sediments and soil; with the zone of saturation being referred to as the 'watertable'. Watertables can discharge into wetlands at various scales in time and space. For example, some upland creeks can keep running for a few weeks after sustained heavy rains, before drying up. This is assumed to be from short lasting shallow watertables discharging directly along the creek channels. However, this is a minor component of inflow for arid NT rivers compared to those in regions of higher and more regular rainfall. In some cases, soaks may be water-table features rather than the result of confined aquifer discharge. Most of the time and in most places in the arid NT, watertables are very deep, if present at all. Major exceptions to this are some of the main salt lake systems and some saline swamps such as Stirling Swamp in the Ti Tree Groundwater Basin. In these situations the discharge zone is typically spread across a large area and is associated with a topographic low forming a 'window' on the watertable. Groundwater discharge into salt lakes may include more than one distinct aquifer, such as at Lake Amadeus. Jacobson (1996) reports that regional discharge of an unconfined aquifer has created and sustains the salt lake, whilst at some points in the lake, confined aquifer discharge creates relatively fresh springs.

Patterns in Surface Runoff

Although ground water has a profound influence on the permanence and ecology of some wetlands, the majority of the water in arid NT comes from surface runoff. This includes salt lakes and most spring-fed pools. Runoff occurs when surface soil is saturated such that ongoing rainfall cannot soak into the ground and flows over the surface. Depending on the terrain, such runoff may be concentrated into drainage channels or may collect in 'run-on' areas. Water moving over the land in this way is also called sheet flow. Some but not all run-on areas are wetlands. Most of the water in large wetlands comes from runoff that has concentrated in major rivers and creeks. The major rivers are generally dry on the surface, running only when heavy rains fall in the catchments. Sometimes they burst their banks and flood out on the adjacent plains and in some places swamps in the adjacent plains are filled from distributary channels. These are minor channels that flow out from larger channels.

The pattern of rainfall through space and time has an important influence on the inundation frequency and persistence of wetlands. Most of the wetlands in the region are temporary and inundation patterns are as unpredictable as the rainfall. A single intense rainfall event or a series of events from the same cloud

system can cause rivers to run or flood; even in relatively dry years. Rivers may run for only part of their lengths or throughout. Some large lakes and swamps may stay dry for several years, yet once full they may be topped up in successive rain events without fully drying out in between.

Various authors have analysed the flow patterns of Australian rivers and noted great variations, especially in the arid-zone (e.g. Puckridge et al. 1998, Boulton & Brock 1999):

‘flows in Australian streams and rivers are nearly three times more variable than the world average, and those in Australian arid-zone streams are especially variable’ (Boulton & Brock 1999, p.18, citing McMahon *et al.* 1992).

The flow regimes of the arid NT are among the most variable in arid Australia, with extreme fluctuations between zero flow (for up to several years), and large intense floods. The duration of channel flows can range from a few hours to many months depending on the intensity, duration, extent and frequency of rainfall. Typically flows are brief, lasting a matter of days or weeks. In rare circumstances flow extends for a period of months. For example, surface water ran in the Todd River at Alice Springs for 67 days in 1974 (Kotwicki 1989 citing Verhoeven) and sections of the Finke River reputedly ran for most of an 18 month period in 2000 and 2001.

Stream flow gauging data exist for various arid NT rivers which would allow their flow regimes to be quantified, but such analysis is beyond the scope of this study. Barlow (1988) analysed stream gauging data for the Todd River, from 1952 to 1988. In that period there were three years of no or minimal stream flow, of which two were consecutive (and 2 years of no data) with the maximum flood height of 3.98m recorded in March 1988.

The rainfall data for the study area indicate that stream flows are more reliable in the north of the study area than in the south.

In recent decades, a conceptual model of water flow and nutrient regimes has been developed for rivers with variable flow, called the 'flood pulse concept'. The following is a summary extracted from Puckridge et al. (1998):

‘the concept deals only with pulses that overflow the banks ...[and is] based on large tropical rivers’ (Puckridge *et al.* 1998, p 55).

They suggest ways of expanding the flood pulse concept to wider applicability:

‘regular pulses of river discharge are a key factor in the dynamics of river-floodplain systems’.

Ongoing study of the Coongie Lakes area of the Cooper Creek system have provided insights into the floodplain ecosystems of arid Australian systems with episodic floods.

A model called DRY/WET was formulated to describe the ecological dynamics associated with episodic floods in rivers in the Australian arid zone and was based on studies of the Coongie Lakes area of the Cooper Creek system (Puckridge *et al.* 1999). This model may have limited applicability in the NT because of important differences in rainfall patterns and the landform of the floodplains. A subsequent study of selected Lake Eyre Basin rivers is currently underway, called ARIDFLO (Puckridge *et al.* 2001).

In the arid NT, intense episodic rainfall events have an important influence on patterns of wetland inundation as well as mitigating the prevailing aridity of the general landscape. Additional information on describing the frequency and duration of inundation events is presented in chapter 5 in the discussion of attributes for classifying wetland types.

3.2 Geology and Paleoclimate

Past climates are part of the key to understanding the contemporary distributions of wetland plants and animals, particularly those with poor dispersal mechanisms. Wetland environments are assumed to have been more widespread and less temporary during various past periods of moister climate. Similarly, at times, drainage systems have been more active than at present and at times are presumed to have sustained year round flow. Such times are referred to as 'pluvial' periods, although evidence is still inconclusive as to their timing. It is also believed that past drainage networks and many of the present day rivers had more connectedness with each other.

The Origins of the Biota

One of the defining characteristics of arid NT wetlands is the occurrence of fish, aquatic invertebrates and aquatic and semi-aquatic plants that are separated by great distances from other populations of the same or related species. These disjunct populations result from some combination of contemporary dispersion and relictualism. Relictual species are those with highly restricted populations believed to be relicts of previous more widespread distributions; often associated with a wetter climate. Accordingly, some contemporary wetlands or their biota may be relicts of previously more widespread wetlands (Williams 1998c; Davis & Froend 1998; Morton *et al.* 1995; Latz 1996, Williams & Allen 1987; Keast 1959). Isolation also occurs through landscape formation processes at various scales in time and space. Changing climates have interacted with geological processes of landscape uplift to drive the erosion and deposition to create the contemporary landscape, drainage networks and wetlands. Periods of aridity are associated with wind driven erosion and the creation of sand dunes. Wetter periods are associated with the action of rivers in transporting sediments and with larger and more interconnected wetland systems.

Williams and Allen (1987) summarise knowledge of the origins of the fauna of Australian inland waters and Allen *et al.* (2002) discuss the evolutionary origins of the fishes.

Geological History

The information presented below commences with a brief account of the geological development of the landscape of central Australia and the relationship between the formation of the Australian continent and past climate. This sets the time scales for subsequent discussion of more recent prehistoric climates of the past tens of thousands of years.

Popular science education has created a general awareness that large parts of central Australia were once occupied by a vast inland sea or seas. It is important to note that the vast sea or seas were far back in geological time, before the Australian continent existed as we now know it. The rocks of the Amadeus Basin extend roughly from Alice Springs to Uluru (Ayers Rock) and are formed from sediments deposited in marine waters at various times between about 850 and 400 million years ago (Ma) and at its largest the Amadeus Sea (850-750 Ma) extended several hundred kilometres in all directions from the location where Alice Springs is now (Thompson 1991). The most recent major uplift occurred around 340 to 310 Ma on the northern edge of the Amadeus Basin, called the Alice Springs orogeny (Thompson 1991), creating the precursors to the present day MacDonnell Ranges. The once vast mountains are now mostly eroded away, with the resulting sediments over 3km deep (Thompson 1991). However, the remaining mountains still create some active drainage including towards the present day Lake Amadeus. Various other marine basins resulted in sedimentary deposition to form the Georgina, Wiso and Ngalia sedimentary basins (Thompson 1991). Many of the rocks that form the hills and ranges of the present day are of even older origin than the sediments of the Amadeus Basin, including the Musgrave and Mann Ranges in the south and the Arunta Block to the north.

Even when the Australian continent developed to approximately its current size and shape, it did not occupy the same place relative to the poles, the equator and other landmasses. Australia is believed to have separated from the Gondwana super continent about 53 million years ago (Beckman 1996). There is fossil and pollen evidence that Australia had a generally cool wet climate at that time (Truswell & Harris 1982). When Australia separated from Antarctica, global oceanic and atmospheric circulation systems would not have resembled their current patterns until continental drift moved the various continents to approximately their current positions. One major ongoing influence on the climate of central Australia would have been the distance from the coast and a correspondingly low rainfall relative to the whole continent (Williams 1984).

For a more detailed introduction to the geology of the area and mountain building and sedimentary deposition, readers are referred to Thompson (1991) and to Jacobson (1996).

Paleoclimate and Vegetation

Information on past climates comes mainly from studies of sediments and organic matter trapped within them, including pollen, but also from geological features created by relatively recent glaciation around the world and chemical analysis of polar ice deposits and organic matter trapped in ice. Wetlands are particularly important areas for the storage of pollen that can be used to study past climates and vegetation.

Studies of vegetation change in response to climatic change and evolution draw largely on pollen in the sediments of ancient swamps and lakes (the study of palynology). Examples for central Australia include Bowler (1982) and Truswell and Harris (1982) in the *Evolution of the Flora and Flora of Arid Australia* (Barker and Greenslade 1982). Bowler provides an account of patterns of aridity across the continent going back to 20 million years in time when the spatial arrangement of the continents was significantly different from today and global atmospheric patterns were correspondingly different. Truswell and Harris discuss the evolution of Australian flora and the past vegetation of today's arid zone from even earlier in geological and evolutionary time. In the distant past, today's arid zone was covered in rainforest (Truswell & Harris 1982), however that was prior to the existence of most of today's species and barely relevant to understanding present day relictualism.

Williams (1984) indicates that the major drainage systems of central and western Australia became 'defunct' during the Miocene (about 10 million years ago). At that time they ceased to form coordinated or integrated networks.

In more recent times (past 2.5 million years) climate fluctuations have possibly resulted in the present lakes being larger and more permanently inundated at various times.

Dodson (1994) reviews Australian vegetation history and response to climate changes in the Quaternary (back to about 1.8 million years ago) including a paragraph on the arid zone in the past 10,000 years. However, there is scant evidence for the arid zone. A map of vegetation history sites in Dodson (1994) shows a major site at Lake Frome in South Australia and a minor site closer to the NT, in the Dalhousie area, and Barlow (1994) refers to pollen analysis of Eocene Hale River deposits in central Australia.

In relatively recent geological times (last few million years), when the landscape has been broadly the same as now, the world has experienced alternating glacial and interglacial phases, as described by Beckman (1996) and summarised below. The glacial periods (ice-ages) have been relatively dry and cool, with the interglacials at the opposite extreme of warmer and moister weather. Incidences of each of these extremes have lasted a few thousand years, separated by much longer periods of less dramatic fluctuations. The last ice age peaked about 18,000 years ago and we are now experiencing an interglacial climate. Barlow (1994) observes that in the Australian arid zone the driest periods are associated with lower temperatures rather than higher ones.

Various authors have suggested the timing and nature of climate changes in arid Australia during the past tens of thousands of years; the period of most relevance to interpreting both the present day distributions of wetland biota and the phenomenon of relictualism. A recent synthesis of information for past climates in Australia is found in Allan and Lindesay (1998). An earlier, more detailed synthesis of information and evidence on past climate variations for the Australian arid zone can be found in Williams (1984), who indicates that during the glacial-interglacial cycles of the past 2.5 million years, 'the climate of Australia has probably oscillated from relatively warm and wet through cool and moist to cold and dry on at least twenty occasions' (Williams 1984, p.72). Around 30,000 years ago, central Australia experienced a significantly wetter and cooler climate than at present, becoming dry and cool towards the glacial peak (20-18,000 years)(Williams 1984). Kotwicki (1989) cites Bowler (1978) to the effect that the ancestral Lake Eyre, called Lake Dieri, was constantly filled for a long period from about 45,000 to 25,000 years ago. It should be noted that most of this filling could have been predominantly from distant catchments in the north east, which now reach the lake though the Georgina and Diamantina Rivers and Cooper Creek. Central Australia would probably have been relatively dry due to its distance from coasts, but quite possibly wetter than at present. Lampert (1989) states that for the south-eastern section of the arid zone, between 10,000 and 5,000 years ago conditions were the moistest and warmest of the past 30,000 years. It is possible that the arid NT was correspondingly moist and warm and many of the rivers may have flowed much more frequently than at present, if not continuously. In contrast, about 18,000 to 15,000

years ago the centre of the continent was possibly so arid as to preclude human occupation (Lampert 1989).

English (1998a & 1998b) discusses the paleoclimate and geomorphology of the present day Lake Amadeus and cites evidence from Chen and Barton (1991) that a 'fluvial lacustrine phase persisted in the present day Lake Amadeus for at least 5 m.y. [million years] before the onset of hyper-arid Quaternary conditions' with aridity generally intensifying from 2 Ma (million years ago) to 10,000 y BP (English 1998a, p.60) (note: BP = before present). Thus, around one million years ago, Lake Amadeus may have been a freshwater lake, but then became saline before becoming generally dry, as summarised by English (1998a):

'Aridity intensified during the Pleistocene (2 Ma-10 000 y BP) although the whole Quaternary is characterised by oscillating climatic regimes. By 750 000 y BP, saline conditions prevailed at Lake Amadeus (Chen & Barton 1991), which contracted, dried up and evolved into a groundwater discharge zone and salt lake. According to work elsewhere in central Australia, the last major channel-sand loads accumulated during two interglacial periods around 250 000 and 110 000 y ago (Nanson *et al.* 1992).' (English 1998a, p.60)

3.3 Geomorphology

Wetland Landforms and Development

A detailed examination of wetland geomorphology in the arid NT is outside the scope of this study but it is important to understand its dynamic nature. Pajmans *et al.* (1985, p15) describe wetlands as ephemeral features of the landscape, because many wetland types are created and destroyed relatively quickly compared to other elements in the landscape.

Arid NT wetlands are predominantly formed by processes of wind and water movement; both in the erosion of surfaces and the deposition of barriers to water movement (e.g. river levee banks, sand dunes). Also, various human earthworks modify existing wetlands and create new ones but they are not considered here. Glaciation, volcanism and earthquakes have not had an obvious role in forming present day landforms in this region, unlike some other parts of Australia. Large meteoritic impacts have been involved in the formation of some landforms, but not to the extent that they are an important part of wetland geomorphology.

Most wetlands occur in closed depressions (basins) which over time are infilled with water born sediments or are breached when a retaining barrier is dissected by water flow. Many channel based wetlands are also ephemeral in that channels on lowlands change their exact course and even waterholes in rocky gorges may be scoured out or infilled with sediments in particular flow events. Pickup (1991) discusses geomorphological process in floodplains (in the broad sense) and Patton *et al.* (1993) present a detailed analysis of the lower Ross River area where massive movement and deposition of sediments has occurred during extreme flood events in the past thousands of years. Typically, only extreme flood events influence erosion and deposition in the broader landscape outside of established channels and Pickup (1991) emphasises the overriding importance of sporadic mega-floods in central Australian landscapes, which far outweigh the effects of more frequent river flows such as those recorded in the past 100 years.

Rainfall runoff and erosion are influenced by factors such as drought and contemporary grazing as well as rainfall intensity (Pickup 1991). Changing fire regimes may also be important (P.Latz pers. comm.). Indeed large and intense fires can have a more pronounced effect on vegetation cover than drought.

During major river flows, large amounts of sediment in the channel are mobilised by mixing with water. Therefore, river channel depths can markedly increase during flows. Barlow (1988) estimated that stream sediments in the Todd River were disturbed to a maximum depth of 3m below the pre-flood river bed during the 1988 flood. However, cross-sections of the river bed prior to and following that flood showed little change. The rates at which river levels rise and fall through a flow event probably influence the manner in which sediments are scoured from the river and redeposited. Thus some waterbodies may be deepened in one flow event and filled in with sediment in another. The amount of vegetation cover and the intensity of rainfall events also influence runoff and flow patterns (Pickup 1991; G. Ride pers. comm.).

Past climate changes have had an important influence on the geomorphology of depositional features in the landscape; particularly sand dunes but also sand plains and alluvial plains and fans. Periods of higher rainfall are presumed to have resulted in increased fluvial erosion in upland areas and sediment transport to lowland areas. In drier times, winds move and structure sediments, such as in the formation of sand dunes. Various authors present evidence that the Simpson Desert dunefields were actively formed during a much drier and windier climate associated with the last ice age; between 25,000 and 13,000 years ago (Wasson 1984). Jacobson (1996) dates the stabilisation of dunes in the Lake Amadeus area as occurring in the period of 14,000 to 34,000 years BP, based on thermoluminescence dates of dunes at Yulara and Curtin Springs.

Salt lakes and claypans are predominantly flat due to the erosive action of wind across their unvegetated surfaces. Salt lakes are formed by the concentration of saline ground water which discharges into them and many have permanently saturated brines in the soils, even though the surface may be a dry saline crust (Jacobson 1996).

Where saline playas have become isolated from the ground water discharge system, they may become vegetated, and consequently aeolian (wind borne) sediments may be trapped: a process described as 'playa capture' (Jacobson and Jankowski 1989). Claypans east of the Stuart Highway, in the Karinga Creek paleodrainage area may also be 'abandoned playas' being 'well above the regional water table' (Jacobson 1996, p. 261).

Various authors give accounts of the geomorphology of present day landscapes, including wetlands. A valuable general summary of the processes of erosion and deposition that form and modify wetlands is given by Paijmans *et al.* (1985) in *Aspects of Australian Wetlands*. More detailed accounts of the geomorphology of the arid NT can be found in texts such as Mabutt's *Geomorphology of the Alice Springs area* (1962) and *Desert Landforms* (1977) and a useful summary is given for the Simpson Desert region by Purdie (1984).

Large Prehistoric River Floods

Large flood events have a particularly important geomorphic influence, through the erosion and deposition of sediments. New swamps, claypans and watercourses may be created by large floods whilst others may cease to function as wetlands for many years because water has been diverted along new or different paths. Studies of the Todd and Hale rivers have indicated that those watercourses have significantly changed their paths in recent thousands of years with floodout areas moving over 100 km (M. Burke seminar).

Studies of river geomorphology indicate that there have been various extremely large floods in the past few thousand years that exceed those experienced in the past 100 years of written records (Pickup *et al.* 1988; Pickup 1991; Paton *et al.* 1993; Bourke 1994, 1998 & 1999). These are sometimes referred to as mega-floods or paleo-floods and are very important in landscape formation and modification. Whether such floods correspond to climatic fluctuations or are extreme events within the current climatic regime is perhaps just a matter of definition. Sediment dates indicate that a mega flood occurred on the Hale River in the order of 1000 years ago, with slack water deposits in Ruby Gap National Park measuring 12.5m high (Burke 1999).

English (1998a) reports a 1km wide swathe cut through the sand dunes, that extends north from the termination of the channel of Britten-Jones Creek and towards Lake Amadeus. It is not known when the large flood event occurred which cut through the dunes, but in 1974 water flowed along the swathe (G. Griffin, pers. comm., cited in English 1998a).

Knighton and Nanson (2000) note the most recent major pluvial period for the Cooper Creek as having been about 100 ka BP (i.e. 100,000 years ago).



4. Overview of Major Drainage Systems

Scope

This section describes the general characteristics of the drainage systems in the arid NT. Under the wetland definition adopted for this study, rivers and creeks are wetlands, as well as being sources of water to other wetlands such as swamps and lakes.

Extensions to pre-existing mapping of drainage lines are presented. The division of the study area into major drainage basins is discussed and changes are suggested to the existing national drainage basin boundaries. Summary descriptions of the major creeks and rivers in each basin are presented.

4.1 Overview of Drainage Features

River flows in all of the drainage systems of the arid NT are temporary and all drain inland (athalassic) rather than to the sea. The major river systems are also mostly isolated from each other and are consequently described as ‘uncoordinated’ (e.g. Finlayson *et al.* 1988; and Fleming 1993a) or endorheic (Boulton & Brock 1999). Endorheic regions are areas in which rivers arise but which do not reach the sea as they terminate in closed systems or dry courses (Lincoln *et al.* 1998).

The term drainage or river system is used here to refer to drainage channels that are connected by surface water in normal flow events. This includes connection by interim floodouts.

Most of the drainages commence or ‘rise’ within the arid NT, whereas, most arid zone rivers on other continents carry water from higher rainfall areas where they emanate (Unmack 1995). In Australia too, most of the major inland rivers originate in relatively wet uplands before flowing through arid and semi-arid areas (Thoms 2001). Because they rise in the arid zone, most of the arid NT rivers have particularly low and infrequent flows. The exception to this is the Georgina River system, which rises to the north in the black soil plains of the semi-arid, Barkly Tableland, straddling the NT – Qld border. Only one other drainage of more than a few kilometres length, rises outside the arid NT – Britten-Jones Creek – for which the main catchment is the Musgrave Ranges, just over the South Australian border.

The major drainage systems that emanate from within the arid NT all rise in upland areas where most surface rainfall runoff feeds into clearly defined channels. Some of these combine to form major rivers that extend for tens or hundreds of kilometres. In other areas the minor creeks and rivers extend only a short distance from the uplands into the surrounding plains, before terminating. Some of these virtually sink into the sand, but in some places clay soils confine surface waters in basins that hold water for many months. Very few sections of river flow through obvious valleys once they have emerged from the ranges that initiate them.

Many of the major rivers are discontinuous, such that their surface channels diminish or disappear and then reform. The floodplains that separate the defined channels are called floodouts. The term floodout has wide usage in the arid NT and includes places where a drainage channel becomes subdivided, indistinct or disappears completely and water from the channel is dispersed across a plain or between dunes. They occur both at the final termination of a river system or at some interim point. Water flows into or across the floodout as either sheet flow or by minor channels, which can occur in braided patterns (also called anastomosing or reticulated).

Some creeks and minor rivers terminate in saline lakes as typified by Napperby Creek flooding into Lake Lewis. Conversely, most of the large saline lakes are not currently fed by major drainage channels.

Many of the major drainage channels have interim floodouts where the channels become ill defined or braided and become more defined again down stream. In some cases rivers and creeks floodout in this manner and do not re-form, yet will still supply floodwaters to basins lower in the catchment, via sheet flow across the landscape. None of the major rivers have a floodplain of braided channels on the scale of the Cooper Creek and Diamantina River.

Despite the various mountain ranges that are a distinguishing feature of the arid NT, the vast majority of the land surface is of low relief with very few drainage channels. Some of these plains and dunefields are dissected by the large rivers generated in the hills. Boulton and Brock (1999) use the term 'arheic' for these areas, meaning an area in which no rivers arise (Lincoln *et al.* 1998). In extreme rainfall events water may flow across the land surface in vast sheets for substantial periods of time (days and possibly weeks rather than hours). An example of this occurred in the west of the study area in March and April 2001, and two satellite images illustrating that event are presented in appendix 2.

Paleodrainage channels occur in some of the flat areas. These are subterranean features where relatively unconsolidated sediments have filled in ancient valleys and watercourses, providing a conduit for groundwater flows. Descriptions of their formation are given in English (1998a & 1998b) and in (Wischusen 1998). A some-what loose, and perhaps erroneous, use of the term paleodrainage refers to minor drainage channels on the surface, in the proximity of the subterranean features, such as in the Sangsters Bore area of the Tanami Desert.

Extensions to Existing Drainage Mapping

Existing drainage mapping did not include an adequate dataset at a more general scale than 1:250,000. Existing 1: 1 million mapping was found to be too inaccurate for the purpose of analysing drainage systems and water supply and connection between wetlands. It was also inadequate for creating summary maps for inclusion in this report. Two exercises were undertaken to address this.

The first exercise was to create a simplified representation of existing mapping of major drainages. The existing 1:250,000 digital data of drainage channels were used to create a simplified dataset at the same resolution. This involved selecting a subset of existing drainage arcs and in some cases adding new connector arcs. The resulting dataset is deemed to equate to a mapping scale of about 1:500,000. From this, further subsets were created and the line elements generalised (vertices/points along the lines removed) for mapping at smaller scales such as the maps in this report.

The second exercise was to map surface water connections between channels. This was done interactively with satellite images showing water in the floodouts. Initially this task was restricted to connections between channels that are mapped on the 1:250,000 map sheets. However, satellite imagery showed that even when there is no channel, in many cases floodout waters move across the landscape along quite linear paths. A line was digitised along the middle of these features to show extensions of river flow into Lake Lewis and along terminal floodouts. Some of the maps in this report include these extensions and connections in the depiction of major rivers. Figure 8 above shows the distinction between the previously mapped channels and our mapping of flow extensions.

Further details of these two drainage mapping exercises are included in the mapping chapter.

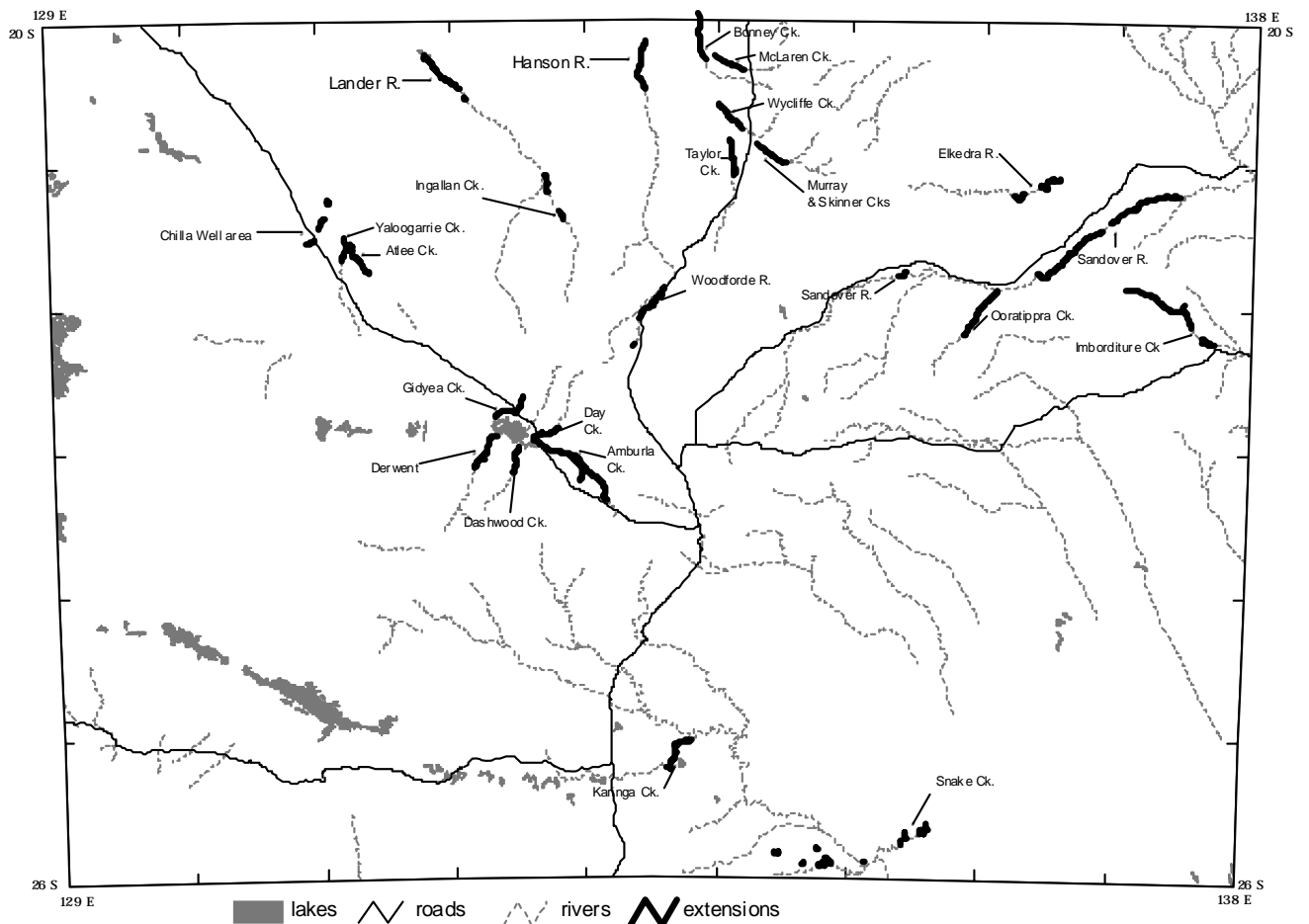


Figure 8. Major drainage lines and connections and extensions mapped from satellite imagery.

4.2 Drainage Divisions and Basins

The Australian Water Resources Commission defines 245 drainage basins for continental Australia, which are aggregated as 12 drainage divisions. The basins were originally defined by the Australian Water Resources Council in the early 1960s, with some minor modifications since (internet site of Bureau of Meteorology /hydro/wr/basins). These basins and divisions are used for summarising the distribution of important wetlands in *A Directory of Important Wetlands in Australia, Third Edition* (Environment Australia 2001). The arid NT is covered by part of just two of the national drainage divisions: Lake Eyre (44.4% of the study area) and the Western Plateau (55.6% of the study area). There are 9 corresponding nationally defined basins, as shown in figure 9. It is important to note that the nationally defined river basins are broadly defined, such that some include more than one distinct river or drainage system. There is no consistent mapping of the catchments of individual drainage systems of the arid NT. Small scale catchment mapping has been undertaken for some of the conservation reserves. This has been done using a digital elevation model based on 1:100,000 scale digital terrain data (D. Schunke pers. comm.). There has also been some broader scale mapping of the Finke River catchment (G. Ride pers. comm.).

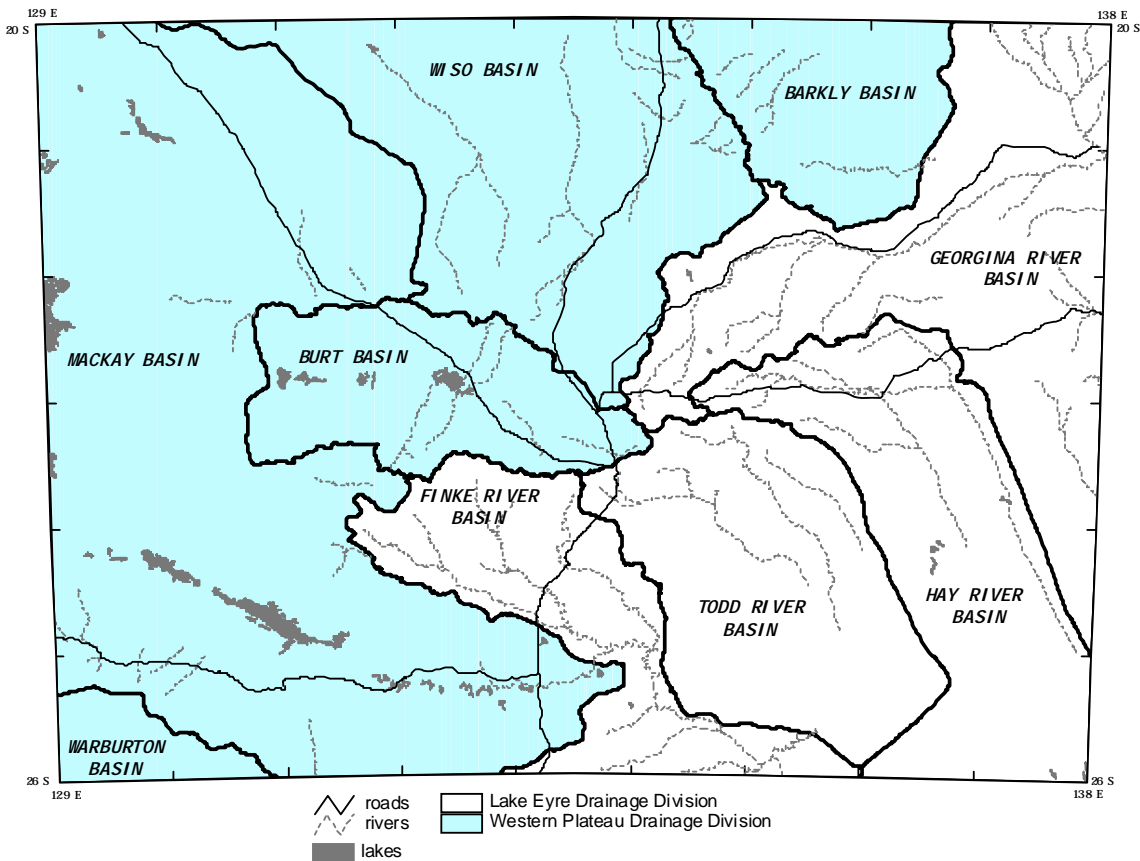


Figure 9. Map of nationally defined drainage divisions and basins, with major rivers. *Drainage divisions and river basins refined as defined by the Australian Water Resources Commission (Environment Australia 2001).*

Revised Mapping of River Basins

The currently defined Australian Drainage Divisions and River Basins were reviewed as part of this inventory of arid NT wetlands. The review was undertaken as a result of observations and information that indicated inaccuracies in a number of the nationally defined river basin boundaries. The distribution of catchments is important for understanding and reporting the nature and distribution of wetlands in the study area. The method used to refine the basin boundaries is presented below followed by a discussion of the results.

Method

The method was based on terrain analysis using a digital elevation model (DEM) in a geographic information system (GIS). The watershed tool within TNTMIPS V5.9 software was used with the AUSLIG Geodata 9 second DEM (version 2). The DEM cell size of 9 seconds corresponds to roughly 280 x 280 metre. Four levels of watersheds (with pourpoints) were defined by progressive basin fill and then digitally overlain on the existing Australian River Basin coverage.

In areas where the DEM generated basin boundaries were substantially different from the nationally defined boundaries, manual checking was conducted. This used the 1:250,000 mapping of drainage, knowledge gained from field observations, previous catchment studies, information from Landsat images during periods of flooding, and more detailed topographic and radiometric data from the Northern Territory Geological Service (NTGS). The radiometric data were used to define the spatial distribution of paleo-floodouts by interpreting alluvial sediment distribution.

Results

The watershed boundaries defined using this relatively recent DEM included some significant variations from the currently defined river basins. In mountainous and hilly terrain the generated watershed boundaries were found to be locally less accurate (100s of metres) than the existing boundaries. This is because the density of mapped drainage lines provides a more accurate basis for separating catchments than the resolution of the DEM. In other areas, the boundaries resulting from the DEM analysis indicate the need for changes to the national basin boundaries. More detailed analysis with a finer scale DEM could be conducted to define new boundaries.

The differences are shown in figure 10 and in table 6, with the most substantial changes being to the Finke, Mackay, Todd and Burt basins.

Table 6. Areas of national drainage divisions and DEM derived basins in the arid NT

Drainage Division	River Basin	Area in arid NT (nationally defined boundaries) km ²	Area in arid NT (new DEM generated boundaries) km ²	Difference as % of arid NT (612,830 km ²)
Lake Eyre	Finke River	43,912	61,482	+2.87
	Todd River	59,637	57,134	-0.41
	Hay River	62,838	63,803	+0.16
	Georgina River	89,199	89,525	+0.05
Western Plateau	Barkly	31,749	32,931	+0.19
	Wiso	85,122	83,658	-0.24
	Burt	38,824	36,947	-0.31
	Mackay	191,873	177,468	-2.35
	Warburton	9,662	9,832	+0.03

Areas determined from the national basins coverage and refined coverage in Albers Equal Area projection.

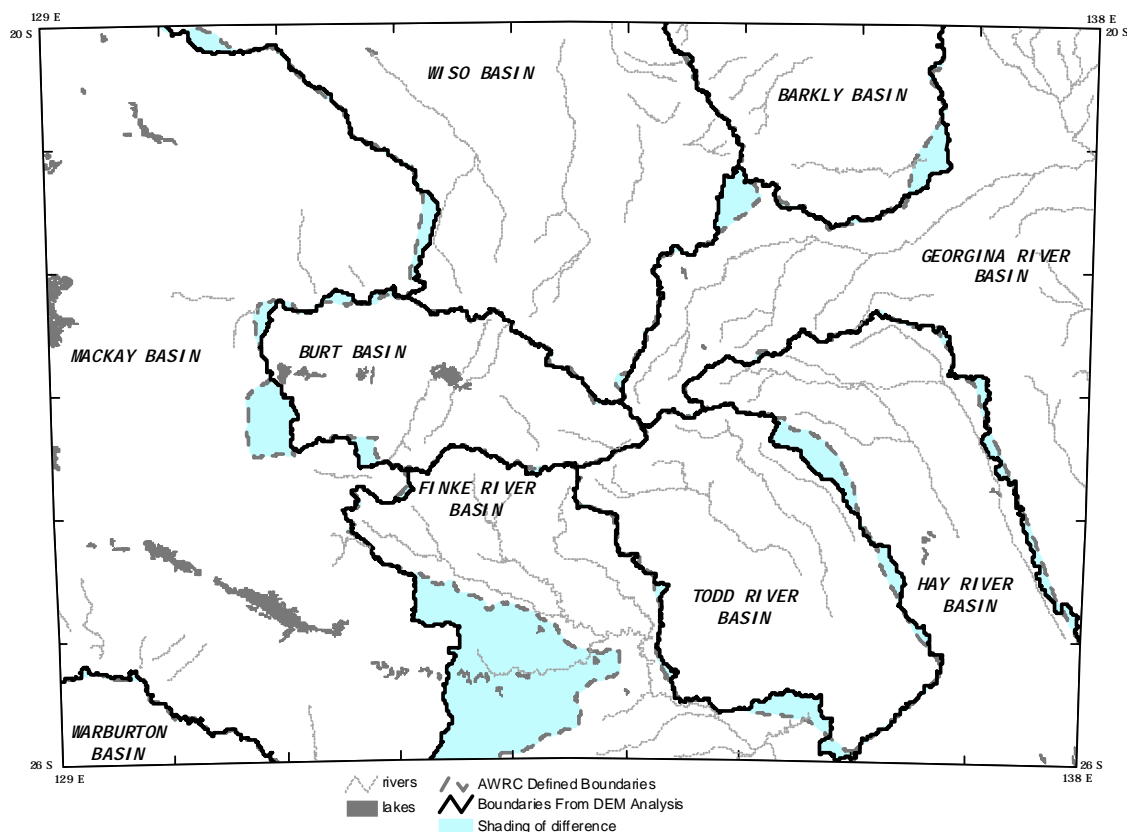


Figure 10. Difference between DEM derived basin boundaries and those of the Australian Water Resources Commission (AWRC).

The largest single boundary change is the inclusion of the catchment area of the Karinga Creek (16,600km²) in the Finke Basin instead of the Mackay Basin. This also changes the boundary between the two drainage divisions. Reports of the Karinga Creek flowing into the Finke River (G. Ride and L. Murphy pers comm.) initiated the investigation of the connectivity of the Karinga Creek to the Finke River. The connection is not mapped on the 1:250,000 topographic map but is clearly evident on satellite imagery from 2000.

It is also proposed to expand the area of the Finke River Basin at the expense of the Todd Basin. This change would incorporate all of the Finke River floodout within the Finke River Basin.

The boundary between the Western Plateau and Lake Eyre drainage divisions needs to be moved so that the Elkedra River does not cross the boundary.

The other recommended modifications of basin boundaries are mostly small and of limited significance to the distribution of wetlands. The changes are mostly justified by the terrain rather than observations of water movement.

4.3 Summary Descriptions of Each Drainage Division

The Lake Eyre Drainage Division

The portion of the arid NT in Lake Eyre Drainage Division is characterised by large rivers that in the past all flowed to Lake Eyre. Currently only the Georgina River in the north-east carries water that regularly reaches Lake Eyre; although, the Sandover River system occasionally connects to the Georgina system via the Sandover floodout.

There are several other rivers that run essentially south-south-east from their sources, towards Lake Eyre, but apart from the Finke and the Field rivers, most of these floodout entirely in the NT.

Finke River Basin

The Finke River has the longest path within the NT of any NT River. It is reputed to be the oldest river in the world (Kotwicki 1989), and although this is difficult to substantiate, the upper portion has followed predominantly the same path for millions of years. It extends from the MacDonnell Ranges into South Australia, with two major tributaries also emanating from the ranges: the Palmer and Hugh rivers. Other large tributaries join the Finke, Palmer and Hugh rivers within the greater MacDonnell Ranges area, including Ellery Creek, Petermann Creek, Walker Creek and Areyonga/Illara Creek. Karinga Creek also connects to the Finke River. Similarly, it is probable that Kalamurta Creek connects by surface flow to the Karinga creek, although no connecting channel is mapped on the 1:250k scale topographic maps.

Two other significant tributaries, join the Finke in its lower reaches: Goyder Creek and Coglin Creek, both of which rise from hills near the South Australian border, including the Beddome Range. Coglin Creek, also known as Charlotte Waters, joins the Finke at the point that it floods out from its major channel, just north of the South Australian border. The initial floodout of the Finke is a broad forest several kilometres wide. Flowing out from this there are two major channels. One continues south over the border and subsequently floods out again in South Australia, with a minor channel re-crossing into the NT to the east. The other channel, known locally as Snake Creek, heads north-east from Mayfield Swamp on the edge of the initial floodout forest. It is likely that the course of the lower Finke was substantially altered by developing dunes during the last glacial maximum (ice age) about 25,000 - 13,000 years BP (Bowler and Wasson 1983 cited in Patton *et al.* 1993). Also, various present day distributary channels may have waxed and waned in relative importance in the past 13,000 years.

Around the South Australian border, south-east of Kulgera, are some of the upper tributaries of Hamilton Creek which connects to Lake Eyre via the Macumba River.

Connection of Karinga Creek to the Finke River

Karinga Creek is mapped on 1:250,000 topographic maps, however the mapped channels stop about 30km from the Finke River.

Wakelin-King's (1989) study of the Karinga Creek salt lakes suggest that they were connected by surface flow from Lake Hopkins in WA through to the Finke River during the period 35,000 to 27,000 years BP. A low calcrete ridge has separated the Karinga Creek catchment from Lake Amadeus to the west, since 27,000 years BP (Wakelin-King 1989).

Leo Murphy (pers. comm.), lessee of Idracowra Station, reported substantial water flows from Karinga Creek into the Finke River about five times in the past four decades. Inspection of Landsat 7 ETM+ imagery from 26th May 2000 indicated a linear water-filled depression connecting the mapped Karinga Creek channel to the Finke River, about one month after the heavy rains of late April (Easter weekend) that year.

Evidence of Connection of the Finke River to Lake Eyre

There is anecdotal information that surface floodwaters of the Finke River periodically connect to Lake Eyre via the Macumba River in South Australia (P.Latz and L. Murphy pers. comm.), however, there is no defined connecting channel. The Lake Eyre Basin Coordinating Group website states there is anecdotal evidence that the Finke flowed into the Macumba in the first decade of the 20th century. Kotwicki (1989) states that a major flood of the Finke in 1967 failed to connect to the Macumba. Aerial survey of the lower Finke River during the 1967 flood recorded that surface waters reached to within 3 to 5km of the Spring Creek drainage line in the Dalhousie Springs area, some 80 km or so from mapped channels of the Macumba River (Williams 1970). Pickup (1991) cites evidence of much larger flows in the upper Finke over the past few thousand years. Depending on coincidence of such paleofloods in the Finke with surface flow in Macumba, it seems possible that surface waters may have connected since the last period of major dune formation associated with the last ice age.

Todd River Basin

The Todd River, Hale River and Illogwa Creek all emanate from the greater MacDonnell Ranges, flooding out into the parallel sand dunes of the Simpson Desert. It is possible that they could extend considerably south of their mapped extents in the event of a mega-flood (e.g. 1 in 1000 years), and it is possible that surface waters of the Todd and Hale Rivers connect with each other in their floodouts in extreme flood events, as noted by Unmack (2001a).

Hay River Basin

The Plenty and Hay Rivers also run south-south-east into the Simpson Desert, in channels that are roughly parallel and 50 km apart from each other. Despite this they are connected by the Marshall River prior to reaching the Simpson Desert. These rivers have their catchments in the Harts Ranges and Dulcie Ranges areas and major tributaries include Arthur Creek, Huckitta Creek and Atula Creek.

Georgina and River Basin

The Georgina River system has part of its regular catchment in the Mitchell Grass Downs portion of the arid NT, and connects to Lake Eyre via the Diamantina River in South Australia. Although there is only a small proportion of this river in the NT, the channel distance from source to sink (Lake Eyre) is much greater than that of the Finke River, and flows are considerably more regular. The catchment of this river extends north into higher rainfall areas, which has a major influence on the frequency and regularity of river flows.

The Sandover River has its main catchments in the northern MacDonnell Ranges Bioregion (Strangways Ranges to Mount Riddock) and in the Dulcie Ranges. From the Strangways emanate Mueller Creek and from Mount Riddock emanates Ongeva Creek which becomes Waite River. From the Dulcies area comes the Bunday River and Ooratippa Creek. The Bunday also has catchment areas in less hilly terrain further west. The Sandover has a large interim floodout on Ammaroo Station, consisting of a 20 km wide flood plain, with no major channels. A minor channel forms upstream of the junction with the Bunday River, which at that point is a far larger channel. Re-invigorated by the Bunday, the Sandover continues east towards the Georgina but dissipates into a vast floodout plain, some 110 km short of the closest marked channels of the Georgina system. However, floodwaters occasionally join up with the Georgina via this floodout as is evident in Landsat 7 TM images 101_75 and 100_75 from January 2001 which show surface water connecting to the Georgina River. The Lake Eyre Basin Coordinating Group (internet site of LEBCG) states there is anecdotal evidence that the Sandover flowed into the Georgina in mid 1980s. There is also anecdotal evidence of a connection in the mid 1970's.

The Field River is the most easterly of those that flow directly to the Simpson Desert (Finke, Todd, Hale, Illogwa, Plenty, Hay and Field). It has its catchment in the Toko Ranges on the Queensland Border, and the undulating plains and hills to the west, which produce Marqua Creek, its major tributary. The Field floods out into sand dunes on the NT side of the Queensland border but with marked channels extending

into Queensland, to within 45 km of the Georgina River floodout complex. As a consequence, it is correctly included in the Georgina Basin.

There is one river of moderate size in the Georgina basin that does not connect to any of the major rivers and that is Lucy Creek, which runs east from the Dulcie Ranges and may once have connected to the Georgina via Manners Creek.

Table 7. Summary statistics of the major rivers and creeks in Lake Eyre Drainage Division

Drainage System	Major Tributaries	Initial Bioregion	Interim & Terminal Bioregions	Highest Point in Catchment (m asl)	Height of highest Major Channel (m asl)	Lowest Point in NT (m asl)	Straight Line Length (km)
Finke River Basin:							
Finke R.	Hugh R., Palmer R., Karinga Ck., Coglin Ck.	MAC	FIN, STP, SSD	1,389 Mt Giles	700	130	450 [†]
Todd River Basin:							
Todd R.	Ross R.	BRT	MAC, SSD	1,164 Mt Laughlin	625	220	200
Hale R.	Cleary Ck., Pulya Ck.	MAC	SSD	1,203 Mt Brassey	660	200	225
Illogwa Ck.	Albarta Ck.	MAC	BRT, SSD	853 Mt Ruby	500	230	140
Hay River Basin:							
Plenty R.	Huckitta Ck., Atula Ck., Marshall R. (+ Hay R.)	MAC	BRT, SSD	1,203 Mt Brassey	600 Corkwood Bore	130	270
Hay R.	Marshall R., Arthur Ck. (+ Plenty R.)	MAC, BRT, CHC	SSD	594	440 Marshal 340 Arthur	70	355
Georgina River Basin:							
Georgina R.	Ranken R., James R., (?Sandover R.)	MGD, CHC, (?BRT)	SSD	220	215	190	>215 [†]
Sandover R.	Mueller Ck., Waite Ck., Bunday R., Ooratippra Ck.	MAC, BRT, CHC, DAV	BRT, CHC, MGD	996 Bold Hill	550	260	270
Field R.	Marqua Ck., Grave Hole Ck.	CHC	SSD	350 Bulinburn Knobs	190	130	>80 [*]
Lucy Ck.	(no longer connects to the Georgina R.)	BRT	CHC	550 West of Picton Springs	320	255	60

In table 7, the highest elevation of a major channel was determined using the AUSLIG 9 second DEM, with subjective assessment of what is a major channel; typically, where large sandy channels form on relatively flat ground. The length of the river was determined from the longest straight line distance from a point in the upper catchment to the furthest mapped terminal channel and was manually measured using a GIS. [†]Note: the length for the Finke River includes the South Australian portion as shown on 1:1M topographic maps; the length for the Georgina includes the catchment to the north of the arid NT and is measured to where the river crosses into Queensland at Lake Nash. ^{*}Note: the length given for the Field River does not include the Queensland portion.

Alternative Grouping of Catchments

The Lake Eyre Basin Coordinating Group (online) divides the Lake Eyre Basin into sub regions that are not based on the drainage basins of the Australian Water Resources Commission. In their regionalisation, the Finke, Todd, Hale, Plenty-Hay and Sandover river catchments form the 'Desert Rivers Region'. The small area on the south Australian border that feeds into the Macumba River is part of their 'Western

Rivers Region' and the catchment of the Field River, near the Queensland border, is part of their 'Georgina/Diamantina Catchment'.

The Western Plateau Drainage Division

The Western Plateau is a vast area and is not unified by a prior common sink in the way that Lake Eyre unifies the Lake Eyre drainage division.

Barkly Basin

The portion of the Barkly Basin in the arid NT is located on the northern side of the Davenport Ranges and contains several large but relatively short rivers; notably the Frew River and Whistleduck Creek, but also Gosse River and Kurundi, Mosquito and Teatree Creeks. None of these connect across the sand plain to the north of the Davenports (Wakaya Desert) to reach the black soil plains of the Barkly Tablelands with its large temporary lakes and swamps and associated drainage channels. The Kurundi and Mosquito Creeks are joined where they flood out, as are the Frew River and Teatree Creek. It is possible that all of these can connect, via Whistleduck Creek in very extreme flood events, although there is no record of this occurring. Due to their proximity to each other, these drainages are usefully grouped together, and could be distinguished from the rest of the Barkly Basin as the northern Davenports sub-basin.

The Elkedra River is the longest of the rivers emanating from the Davenport Ranges, running predominantly east and flooding out into various long lasting swamps. Some water flows further east along unmarked floodways, finally dissipating into a sandplain to the north east of Annitowa homestead. This terminal floodout is about 70km from the marked channels of Georgina River tributaries, and is slightly closer to parts of the Sandover floodout. The Elkedra River may have once flowed to the Georgina River (e.g. Mabbutt 1962) and arguably could be included in the Lake Eyre Drainage Division. However, there is no evidence of a contemporary connection.

Two other substantial drainages flow east from the Davenport Ranges, although not as far as the Elkedra River. These are Gastralobium Creek and Yaddanilla Creek.

Wiso Basin

The Wiso Basin is a vast area that incorporates the eastern part of the Tanami Desert (as distinct from the Tanami Bioregion). In the study area it contains several, mostly unconnected drainage systems. On the west and south west sides of the Davenport Ranges are several rivers of various sizes. They include Skinner Creek, and Murray Creek which share a joint floodout, Wycliffe Creek, Bonney Creek, McClaren Creek and Gilbert Creek. Inspection of satellite imagery indicates that the floodouts of several of these creeks may be joined in large flood events. Skinner and Murray Creeks probably join in typical floods. Skinner Creek then floods out towards Thring Swamp and Wycliffe Creek. Bonney Creek is probably joined by Gilbert and McClaren Creek in large floods.

Taylor Creek rises in the hills around Barrow Creek Roadhouse and floods out to the north of the Osbourne Ranges. There is anecdotal evidence that the floodwaters of the Taylor can reach those of Wycliffe Creek (D.Debney and K.Bethel pers. comm.) and this is corroborated by satellite imagery showing floodwaters of the Taylor extending towards the Wycliffe Creek floodout.

The Hanson River rises in the Anmatjira Range to the south west of Ti Tree Community, and flows north, flooding out into the Tanami Desert. It has several large tributaries and is connected to Stirling swamp. There are no natural permanent waterholes in this drainage system and no documented major swamps in the terminal floodout, but two major swamps in the mid reaches: a large complex of wetland types at Stirling Swamp, which is connected and adjacent to the river; and a large gum-barked coolabah swamp at Mud Hut Well on Bloodwood Creek. The floodout is nevertheless extensive, with surface water extending for over 1km wide in places and many kilometres long. Several broader basins have been identified from quicklook TM images but neither their vegetation nor longevity has been investigated.

The Lander River is the second longest river in the arid NT and runs north into the Tanami Desert; rising in the Ngalurbindi Hills, Reynolds, Anmatjirra and Yundurbulu Ranges. It has relatively frequent flow events (M.Lines pers. comm.). It has a long and extensive floodout, which contains a number of temporary but relatively long lasting in-channel waterholes and effectively terminates at Lake Surprise, the largest freshwater swamp basin in the arid NT. The Lander River continues on to the north of Lake Surprise, but these channels probably rarely carry water. Satellite imagery and aerial observations by Don Langford indicate that Lake Surprise did not fill completely nor utilise these channels during the 2000-2001 wet years. However, in 1974 outflow utilising these channels has been reported (P.Latz pers. comm.). Extensive sections of the floodout and Lake Surprise hold water for many months after inundation and are major wetlands.

Burt Basin

Gidyea Creek, Napperby Creek, Day Creek, Amburla Creek, Sixteen Mile Creek, Dashwood Creek and Derwent Creek are all part of the Burt Basin which drains the Burt Plain; and all run towards Lake Lewis. Although, only the channel of Napperby Creek currently connects directly to the lake, several of the others probably connected via surface waters in February-March 2000 (as documented above). There is anecdotal evidence of Sixteen Mile Creek connecting via surface waters in the big flood events of 1974 (C. Connellan pers. comm.).

Mackay Basin

There are relatively few major rivers in the NT portion of the Mackay Basin, which approximates the western third of the arid NT, with very low relief and drainage systems characterised by minor saline channels (some associated with sub surface paleo-drainages) and saline lakes. Ethel Creek flows west towards Lake Mackay from the Treuer range but marked channels dissipate well short of the lake. Waite Creek (not to be confused with the Sandover River tributary of the same name) flows south from the Treuer Range.

There are various very minor creeks associated with other mountain ranges and several medium sized rivers emanating from the Petermann Ranges. Most of these (Hull River, Shaw Creek, Irving Creek and Armstrong Creek) flow north towards Lake Neale and Lake Amadeus although their defined surface channels peter out in the sand dunes well short of the salt lakes. Only Docker River and Giles Creek cross the border into WA. A single major creek emanates from the Musgrave Ranges on the South Australian border; Britten-Jones Creek which runs north towards Uluru, into the sand plains.

Within the Mackay basin, various creeks rise in the MacDonnell Ranges bioregion and flow out into the Great Sandy Desert Bioregion. The largest two are Kings Creek and Deering Creek and both have associated floodout swamps.

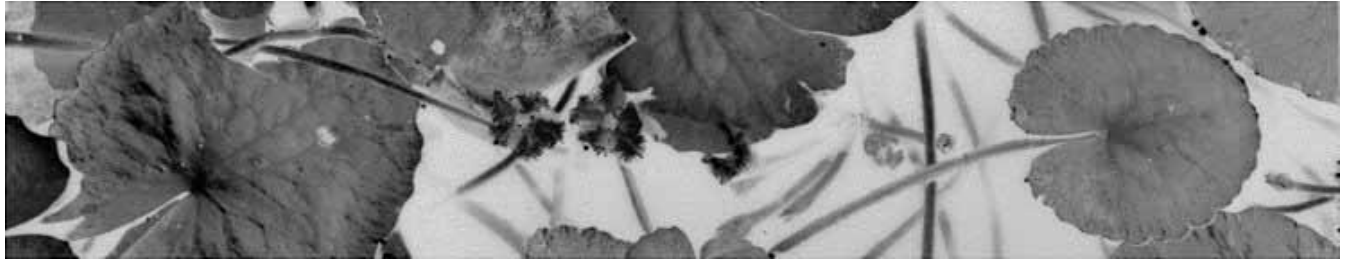
Warburton Basin

The Warburton Drainage Basin extends from Western Australia into the south-west corner of the NT. There are no creeks of any great size in the NT portion and for the study area this area is indistinct from the Mackay Basin.

Table 8. Summary statistics of the major rivers and creeks in Western Plateau Drainage Division

Drainage System	Major Tributaries	Initial Bioregion	Interim & Terminal Bioregions	Highest Point in Catchment (m asl)	Height of highest Major Channel (m asl)	Lowest Point in NT (m asl)	Straight Line Length (km)
Barkly Basin: Flowing to North from the Davenport and Murchison Ranges							
Frew R.	Hatches Ck. (Teatree Ck) and Lennee Ck.	DAV	DAV	605	395	275	100
Whistleduck Ck.	Blackfellow Ck.	DAV	DAV	625	400	290	60
Kurundi Ck.	Kudinga Ck., Granite Ck.	DAV	DAV	602 Mt Cairns	400	320	40
Mosquito Ck.	(connects to Kurundi Ck at floodout)	DAV	DAV	500	400	320	35
Gosse R.	Turkey Ck.	DAV	DAV	555	400	300	65
Barkly Basin (flowing East from the Davenport Ranges):							
Elkedra R.	George Ck.	DAV	TAN	584	445	265	140
Gastralobium Ck.		DAV	TAN	575	390	295	55
Yaddanilla Ck.		DAV	TAN	506	345	280	20
Wiso Basin (flowing West and South-West from the Davenport and Murchison Ranges):							
Edinburgh Ck.		DAV	DAV	525	425	390	15
McClaren Ck.		DAV	TAN	556	390	340	25
Wauchope Ck.		DAV	TAN	500	425	350	15
Wycliffe Ck.		DAV	TAN	570	390	350	30
Skinner Ck.		DAV	TAN	625	450	385	35
Murray Ck.		DAV	TAN	605	460	385	35
Wiso basin (flowing North into or towards the Tanami Desert):							
Lander R.	Ingallan Ck, Crown Ck.	BRT	TAN	1,239 Mt Leichhardt (1,113 Mt Thomas)	670	325	300
Hanson R.	Woodforde R, Bloodwood Ck.	BRT	TAN	1,001	625	350	250
Taylor Ck.		BRT	TAN	697 Mt Gwynne	540	400	75
Burt Basin (flowing into[†] or towards Lake Lewis):							
Napperby Ck. [†]		BRT	GSD	881	675	550	55
Day Ck.		BRT	GSD	885	650	575	40
16 Mile Ck.		BRT	BRT	875	750	640	70
Charley Ck.		MAC	BRT	1,252 Mt Hay	650	600	35
Dashwood Ck.		MAC	BRT	1,531 Mt Zeil	650	590	35
The Derwent		MAC	BRT, GSD	1,118 Haasts Bluff	640	590	35
Mackay Basin:							
Ethel Ck.		BRT	GSD	650	600	480	57
Waite Ck.		BRT	BRT	822 Mt Davenport	600	515	45
Docker R.		CR	GSD	1,029 Dean Range	700	550	40
Hull R.		CR	GSD	1,024	700	500	75
Shaw Ck.		CR	CR	936	690	600	30
Armstrong Ck.		CR	GSD	874 Mt McCullogh	700	550	65
Giles Ck.		CR	CR	821	700	675	10
Britten-Jones Ck.		CR	GSD	1,086	850	560	55
Deering Ck.		MAC	GSD	1,151	700	650	100
Kings Ck.		MAC	GSD	906	610	580	23

[†]Elevation of highest major channel' and 'length' were determined as for the previous table.



5. Classification of Arid NT Wetlands

Scope

There is no world-wide standard classification system for wetlands and perhaps it will never be practical to create one. There has also not been a formal inventory focused on arid Australian wetlands and so there is no existing classification that usefully distinguishes the wetland types in the arid NT. Creation of a classification of wetlands in the arid NT was required in the Natural Heritage Trust funding agreement.

In this section we discuss in detail the nature and purpose of wetlands classification and the various attributes that can be used for classifying arid NT wetlands. This includes attributes used to distinguish between wetlands and drylands. Despite considerable attention on wetland classification in the scientific literature, many terms and parameters are not well defined. A selection of pre-existing and some new terms are defined to describe the variation in the ecological parameters of arid NT wetlands. A classification system for arid NT wetlands is presented and compared to other relevant classifications.

Detailed descriptions of the arid NT wetland types are given in the next chapter.

5.1 Overview of Wetland Classification Issues

The Purpose of Wetland Classification

Wetland classification is a tool for studying and communicating information about wetland environments. It typically involves defining wetland types, to which individual wetlands can be allocated. Classification is a fundamental component of inventory as it underpins mapping and reporting of wetland occurrence.

There are two reviews of wetland inventory and classification in Australia which provide an excellent information base (Pressey & Adam 1995; Barson & Williams 1991).

Pressey and Adam (1995, p.87) included as classification 'any attempts, intuitive or numerical, to group wetlands with common characteristics or to identify the types of environments and biota they contain'. They stated the importance of seeing classifications 'in two ways: (1) as hypotheses about the way in which features of wetlands are arranged in space and time; and (2) as responses to the need for particular types of information for particular purposes, dependent also on the geographical scale of the study and the variability of the wetlands.' (Pressey & Adam 1995, p.95). Similarly, Barson and Williams (1991) listed the following uses of wetland classifications:

- description of ecological units – with certain homogeneous natural attributes;
- aiding resource management;
- inventory and mapping; and
- aiding communication by promoting consistent terminology.

Classification Types and Methods

There are many different approaches to ecosystem classification.

Classifications can be 'a priori' or 'a posteriori' (Pressey & Bedward cited in Barson & Williams 1991), where:

- a priori classifications are constructed prior to survey work and allow wetlands to be pigeonholed during an inventory on the basis of indicators; while
- a posteriori classifications are determined after survey work and are based on analysis of the environmental attributes surveyed.

A posteriori classification based on survey data can include numerical classification techniques.

Many classifications involve identifying, defining, describing and naming wetland types. Wetlands of a given type are more similar to each other (homogeneous) in key attributes than they are to wetlands of different types. However, as noted by Paijmans *et al.* (1985, p.22) 'Many wetlands cannot be precisely classified because of continuous gradations from one into another'.

Classification may also be hierarchical or non-hierarchical. In hierarchical classifications, wetland types are at the end of a classification 'tree' with different environmental attributes used to distinguish branches at each level of the tree. The classification system developed for Western Australia (Semeniuk 1987) is a good example of a hierarchical classification (Barson & Williams 1991). There are some difficulties with the hierarchical approach, as discussed in detail by Barson and Williams (1991), because wetland biota may not distinguish between the upper categories of the hierarchy. For example, wetlands with very similar vegetation may be assigned to different wetland types because they are separated on another attribute, higher in the classification hierarchy; typically landform. This was seen as undesirable by Barson and Williams (1991).

Some classifications do not explicitly define and describe wetland types. They are open ended hierarchies, such that individual wetlands can be categorised at various levels in the classification. This allows new variations in the range and combination of environmental attributes to be described as they are encountered.

Environmental Attributes Used To Classify Wetlands

The key environmental attributes that are generally used to classify the variety of wetland environments are:

- landform;
- substrate (soils, rock);
- scale and spatial arrangement (including complexity or uniformity);
- size;
- inundation regime (permanency, frequency, duration and depth of inundation);
- source of water;
- water and soil salinity; and
- vegetation type and/or characteristic species.

The combination in values of these attributes determines a wetland's 'ecological character'. Documentation associated with the Ramsar Convention defines ecological character as follows:

'Ecological character is the sum of the biological, physical, and chemical components of the wetland ecosystem and their interactions which maintain the wetland and its products, functions and attributes. (Resolution VII.10)'. (internet site of Ramsar: [key_guide_list_e.htm](#))

If the wetland types distinguished in a classification do not have distinctive 'ecological characters', they will not be useful.

Overview of Existing Classifications and General Issues

Although there is no perfect way of classifying any environment, it is important that the system adopted meets requirements for summarising and communicating information.

One of the requirements of the arid NT wetlands inventory is that wetlands be summarised in terms of the Ramsar wetland classification as adopted by *A Directory of Important Wetlands in Australia, Third Edition* ('The Directory': Environment Australia 2001). However, that classification does not adequately distinguish the range of wetland environments in the arid NT. Therefore, there is a requirement for the arid NT wetland classification to be compatible with, but not limited to the Ramsar classification.

Blackman *et al.* (1992) developed a detailed hierarchical classification for wetland inventory in Queensland. Other existing classifications are reviewed by Barson and Williams (1991), including a hierarchical system developed in Western Australia by Semeniuk (Semeniuk 1987; Semeniuk & Semeniuk 1997). Aspects of both the Semeniuk and Blackman *et al.* system have influenced the development of the arid NT system.

Pressey and Adam (1995, p.81) urge wetland scientists and managers to 'test the assumptions involved in the use of classifications, and to ensure that the classifications they use are the most appropriate for their purposes'. They also stress the importance of a good classification: 'The choice of how to group wetlands into types with some homogeneity of features important to tasks is critical. The wrong choice will produce classes which are not informative, in time and space, of the features of interest.' (Pressey & Adam 1995, p.81). We can add to this, that to be useful, classes or types must be easily identifiable in the field, preferably with minimal training. Some compromise is necessary between very detailed classifications, that attempt to distinguish wetland types on relatively subtle differences, and broader classifications into which individual wetlands can be more easily fitted, but which don't distinguish important biological differences.

Pressey and Adam (1995) surveyed Australian wetland scientists regarding inventory and classification. They reported that a majority of respondents viewed classification as tools for particular purposes, typically for understanding environmental variation, such that it would be inappropriate to strive for an all purpose global classification system. Of particular relevance to the arid NT is the following statement:

'a single classification could not serve all needs and, in areas where wetlands were not well known, could confuse and hinder conservation efforts' (Pressey & Adam 1995, p.95).

Furthermore, it is recognised that classifications may be developed 'iteratively as more information comes to hand'. Development of classifications to deal with the temporal variability of many Australian wetlands was seen as important to several respondents and is of great relevance in the arid NT. The above findings and recommendations by Pressey and Adam (1995) all indicate the need for a thorough approach to classifying arid NT wetlands.

Another consideration in designing the arid NT classification was the use of attributes that are easily distinguished by remote sensing (aerial photographs and satellite imagery) and rapid assessment from aerial or ground survey. This was most important as the classification is the basis for mapping and summarising the distribution of wetlands by wetland type (inventory).

Barson and Williams (1991) state that it is important for wetland surveys to collect 'primary data' rather than pigeon hole sites into a predetermined classification in the field. The collection of primary data allows objective testing of classifications, however, during an inventory it may be necessary to allocate a great many individual wetlands to a wetland type. In the wetland survey of the arid NT both approaches were used. Detailed observations were recorded at a subset of sites, whereas at rapidly surveyed sites only general observations and preliminary wetland type were recorded.

A current research project of the CRC for Freshwater Ecology is investigating the ecology of dryland river systems including ways of classifying persistent waterholes and their role as refugia (Bunn & Georges 2000). Although it is based on rivers in the east of the Australian arid zone, it can be expected to produce insights and methods of great relevance to arid NT wetlands.

General Terminology

Various terminology is in use regarding wetland types and landforms ranging from local vernacular to formally defined scientific terms. Given the social and political context of wetland inventory and the need to generate community support for wetland conservation, it is important that the naming of wetland types be grounded in common and widely understood terms. However, it is also important that terms be well defined and that those which are particularly ambiguous are avoided. Various authors have suggested terminology for wetland types and some of the key wetland attributes. Some of these are discussed from an arid NT perspective in the following sections. Some of the terms proposed by others are rejected here on the basis that they are counter productive to general communication. For example the terms 'River', 'Creek' and 'Wadi' were defined by Semeniuk and Semeniuk (1997) as applying to permanently inundated, seasonally inundated and intermittent water courses. In the arid NT all watercourses are intermittent apart from a small number of short spring fed streams. To suggest to landholders that there are no 'rivers' in the arid NT would be unlikely to aid communication.

We have used the word 'swamp' to broadly apply to wetlands characterised by emergent vegetation, following Pajmans *et al.* (1985) but have avoided related terms such as 'marsh'. We use the term 'lake' for large bodies of open water that are not part of a drainage channel. Open water is used for areas with minimal emergent vegetation.

5.2 Definition of Wetlands

The first level in classifying wetlands is to distinguish between wetlands and non-wetlands. On the ground, the distinction is not always obvious (Pressey & Adam 1995). Distinguishing wetlands and their boundaries is particularly difficult in arid environments where most wetlands are temporary and consequently may be dry when encountered. Indeed, there is a common perception that there are few wetlands in the arid NT. This misconception results from poor understanding of the modern use of the term 'wetland' as well as from the general aridity of the study area and the temporary nature of its wetlands. A good definition of wetlands is important for communicating effectively with the various interested parties: landholders, managers, government and the public. Furthermore, wetland definition underpins classification and inventory.

Most definitions use only a few sentences to describe the unifying environmental attributes, but are coupled with a list of wetland types or classification. In this way, the definition and the classification complement each other in explaining what is meant by a wetland.

There is no universally recognised definition, with most studies and jurisdictions creating their own to suit the purpose and situation at hand (Pressey & Adam 1995). Many of the existing definitions include temporary wetlands, which is essential in arid environments. However, few adequately communicate the very long dry periods that occur in many arid NT wetlands.

The following discussion considers the defining attributes for wetlands in an arid environment and presents some of the most pertinent pre-existing definitions. We then present the definition that we have adopted for use in the arid NT.

Pre-existing Definitions of a Wetland

The subject of wetland definition has been widely considered and two Australian reviews provide detailed discussions of the requirements and various definitions in use (Barson & Williams 1991; Pressey & Adam 1995). We draw on those reviews in considering the issue from an arid zone perspective.

Broad Versus Narrow Definitions (and Origins of Contemporary Usage)

The term 'wetland' gained increasing use during the twentieth century in the context of conservation and with a particular emphasis on waterfowl and waders. Modern use of the term 'wetlands' generally includes a broad range of environments that are characterised by an abundance of water relative to the surrounding landscape. This 'broad' use is a move away from the origin of the term. The components of the word imply land that is wet as distinct from deeper waterbodies such as large permanent rivers, lakes

and the sea. Originally, the term wetland was mostly used for areas of waterlogged soil and shallow water with emergent vegetation. This is reflected in some contemporary definitions which exclude deep or flowing water.

The broadening of the term has come from recognising the commonalities of environments that are habitats for plants and animals that are dependent on free water. Free water is water that is not bound up in the structure of soil or in rocks and occurs as waterlogged (saturated) soil or covers the land surface.

Thus, many recent definitions include environments with flowing water, deep water and some include particular marine environments. Barson and Williams (1991) recommend the inclusion of deep water because of the continuum between deep and shallow waters, the interconnectedness of many wetland types, and because deep water areas support an aquatic fauna. Also, they observe that most wetland definitions used by overseas agencies include deep water.

The terms 'deep' and 'shallow' are not consistently defined in wetland literature, but the distinguishing depth is typically 1 metre or 2 metres. The distinction is not very important in arid NT, where most areas which can have inundation more than 2 metres deep, also dry out completely, and therefore are at some stage shallow.

A broad definition is appropriate for the arid NT. The few areas of deep water and permanently flowing water should be included as wetlands due to the strong contrast between any wet areas and the landscape in general.

Water and Dependent Biota

In the first systematic analysis of Australian wetlands at a continental scale, Paijmans *et al.* (1985, p.1) used a broad definition in which the occurrence of waterbirds or hydrophytic plants is an essential criterion for temporary wetlands:

'land permanently or temporarily under water or waterlogged. Temporary wetlands must have surface water or waterlogging of sufficient frequency and/or duration to affect the biota. Thus the occurrence, at least sometimes, of hydrophytic vegetation or use by waterbirds are necessary attributes'

The application and examples of their definition are found in their classification of wetland types including episodic lakes and swamps that are dry most of the time, floodplains and drainage channels and banks. They also state:

'Wetlands...differ from their surroundings by the persistent presence of free water' (Paijmans *et al.* 1985, p.3).

The inclusion of the link between free water and wetland plants and animals is particularly important for arid areas as it addresses the need to define how long an area must remain wet to be termed a wetland. It excludes areas that have no special values for the conservation of wetland plants and animals because they are inundated or waterlogged for only very short periods or only in exceptional floods. At the same time, it includes those wetlands that are only inundated very occasionally, such as the large salt lakes, but which when filled support a distinctively aquatic invertebrate fauna and large flocks of waterbirds.

Since many arid NT wetlands are dry most of the time, wetland plants are often important indicators that an area is a wetland. The term 'hydrophyte', used in the definition of Paijmans *et al.* (1985), is too limiting to define wetland plants in the arid NT, since it is usually used for plants that require 'a large amount of water for optimum growth' or are 'adapted to live in water or very wet conditions' or is even more limited to plants with 'renewal buds below the water' as defined by Lincoln *et al.* (1998). There is a large group of arid NT plants that are restricted to wetland environments, which require inundation to germinate but predominantly grow when surface water has receded.

Since some microscopic plants and animals can rapidly grow and reproduce in tiny puddles of water lasting only a few days, some further clarification is useful for defining wetlands. To include such extremely small and short lasting waters as wetlands may be detrimental to the cause of wetland conservation. Therefore, it may be useful to require that plants and animals must be macroscopic (visible to the naked eye) to be used as determinants of a wetland.

Northern Territory and Australian Government Definitions

There are two pre-existing definitions with which this inventory needed to conform: the definition in the NT Government wetlands conservation strategy and the Ramsar Convention definition (also adopted by the Australian Government).

In *A Strategy for Conservation of the Biological Diversity of Wetlands in the Northern Territory of Australia* (PWCNT 2000) a wetland is 'an area that is:

- covered with water for a substantial period, though not necessarily in every year;
- contains water that is usually shallow, and slow moving or stationary;
- contains water that may be fresh, brackish or saline; and
- contains water for a sufficient period for the plants and animals that live there to require adaptations to cope with or thrive in wet conditions for at least a part of their life cycle.' (PWCNT 2000)

The 1971 Ramsar Convention (Article 1.1) refers to:

'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 ' (internet site of Ramsar).

The NT definition includes the presence of wetland plants and animals and excludes areas which are only briefly inundated, without specifying a minimum length of time. It focuses on shallow and slow moving water without excluding deep water. One aspect in which it is more restrictive than many definitions is that it excludes areas of water-logged soil unless they are initially submerged. In the arid NT this could exclude some small spring fed upland swamps that are rarely inundated.

Importantly for the arid zone, the Ramsar definition includes temporary wetlands, however it does not provide any criteria for how long or often an area must be inundated to be deemed a wetland. Barson and Williams (1991, p10) observe that the Ramsar definition could 'include almost any area with surface water' such as roadways, puddles and playing fields. Another problem with the definition is the use of terms for wetland examples that are not generally used in Australia, such as 'fen' and 'peatland'.

The Ramsar classification of wetland types includes subterranean karst wetlands (e.g. limestone caves) and the Ramsar documentation clearly defines subterranean aquatic fauna habitats that are to be considered wetlands (item 5.6): 'all subterranean cavities and voids with water (including ice caves)'(internet site of Ramsar: key_guide_list_e.htm).

Sampling of bore waters in calcrete aquifers in the NT found many species of aquatic invertebrates (R.Read pers. comm.). It is possible that there is also a unique aquatic invertebrate fauna in saturated soil and sand below and adjacent to rivers and swamps (the hyporheic zone), based on work interstate (reviewed by Boulton 2001). However, due to the lack of knowledge and great potential for confusion and increased scepticism about the use of the term 'wetland', subterranean wetlands are not explicitly included in our arid NT definition (below).

Recent Australian Definitions

A recent Australian definition of wetland is given by Boulton and Brock (1999, p.3):

'A wetland is any area of temporarily or permanently waterlogged or inundated land, natural or artificial, with water that is standing or running, ranging from fresh to saline, and where inundation by water influences the biota and ecological processes at any time.'

This is broad enough to include all the environments in the arid NT that can support populations of wetland flora and fauna, and is very similar to the definition proposed by Barson and Williams (1991).

Our definition for the arid NT is very similar too, but includes explicit mention of long dry periods and a lack of depth and size restriction (see below).

Arid NT Definition of a Wetland

The following formal definition was adopted for defining what is a wetland in the arid NT.

Wetlands are areas of permanent or temporary surface water or waterlogged soil. They may be dry for decades but inundation or waterlogging must be reoccurring and of sufficient duration to be used by macroscopic plants and animals that require such conditions during their lifecycles. They may be natural or artificial, with still or running water which can be fresh or saline. In the inland they may be of any depth or size.

Some landholders and members of the public are sceptical about the use of the term wetland in the arid NT. In order to aid communication the following ‘common language’ definition was used in our project information sheet for landholders.

Wetlands is a term that can mean different things to different people. Our definition is based on an international agreement and includes waterholes, rivers, swamps, clay pans, salt lakes and springs. It also includes artificial wetlands such as dams, sewage ponds and associated swamps.

Wetlands in the arid part of the Northern Territory range enormously in size from vast salt lakes to small spring fed pools. A few hold permanent water but most of the wetlands are dry most of the time. One of the distinguishing features is that following rain, wetlands continue to hold water after the surrounding landscape has dried out; either above the ground or in waterlogged soil.

To be considered a wetland, an area must at least occasionally be wet for long enough that it is used by plants and animals that require waterlogging or inundation during their lifecycles and are visible to the naked eye. Even if they are only filled once every few decades they may still be important for species conservation.

5.3 Landform and Water Source as Attributes of Wetland Type

Major Landform Types for Classification

Landform is the physical attribute of the landscape that can be most easily observed regardless of the state of vegetation or inundation of a wetland. Accordingly it is used here as the primary attribute in a hierarchy of attributes that partially underlies our classification of arid NT wetland types. A basic distinction is made between wetlands that are within the channel of a drainage system and those that are basins or flats. Seepages and springs are also separated at the primary level in our classification due to their distinctive character in arid landscapes. Thus they are treated as a distinct broad wetland type irrespective of their occurrence in basins, watercourses or flats. The exception is springs that emerge directly into permanent waterholes since they are essentially hidden and only influence the ecological character through longevity of inundation.

Basin Landforms (excluding drainage lines)

There is potential confusion about use of 'basin', since it has established use in several different contexts. In describing geology it can refer to large areas of sedimentary deposition, such as the Amadeus Basin. In hydrological usage it can refer to river catchments at various scales, including the entire catchments of major river systems, which are mapped as drainage basins by the Australian Water Resources Commission. At an even broader scale, vast areas of previously or currently linked drainages may be referred to as basins, such as the Lake Eyre Basin and the Murray-Darling Basin. The term is also used in subterranean hydrology for large aquifers systems, such as the Great Artesian Basin.

In the context of landform for individual wetlands, a 'basin' is defined here as holding water across most of its area, at least occasionally, in such a way that the water is not generally flowing. The elevation within the basin (the floor or bed) is usually lower than the surrounding landscape, but water may also be confined by depositional surfaces forming banks above the level of the general landscape; such as sand dunes and levee banks.

The term basin is more broadly applicable than the terms 'lake' and 'swamp' that defined the upper levels of the broad classification applied to Australian wetlands by Paijmans *et al.* (1985). Many arid NT wetlands that are confined in a basin landform may take on traditional characteristics of lakes when full and swamps when only shallowly inundated.

Floodprone Flat Landforms

A broad landform class of 'flats' is incorporated into our classification in order to include broad areas prone to flooding that have an ecological character influenced by inundation but do not hold water for very long in a well defined basin. It roughly equates to the category referred to by Paijmans *et al.* (1985) as 'land subject to inundation'; a category used in 1:250,000 topographic mapping, and which Paijmans *et al.* (1985, p.24) defined as:

'differs from swamps in that the water does not stay long enough or frequently enough for hydrophytic vegetation to develop although it may provide important waterbird habitats. It grades into seasonal or intermittent lakes but is usually less saline, better vegetated and with less distinct borders.'

It incorporates parts of river floodplains and floodouts (defined below). The distinction between a flat and a basin is not always clear, such as for some very shallow, vegetated swamps. Areas that hold water for many weeks to months and have reasonably well defined edges have been generally regarded as basins in this inventory.

Drainage Landforms

Waterholes within drainage lines are effectively basins within channels. The terms 'waterhole' and 'channel' are used here to distinguish the 'in-channel' basins from the other sections or 'reaches' of watercourses.

Waterhole - those parts of watercourses which hold still water after water flow has ceased

Channel - the rest of a watercourse, in which surface water is generally running if present

This definition is useful, although not exhaustive. When river sands are saturated, very shallow minor pools will persist in temporary low spots in the river bed. Where the river flows repeatedly produce a low spot in the same place, in separate flow events, the term waterhole may be appropriate. Otherwise very shallow pools should be considered as 'channel'.

Some channels are more clearly different from adjacent landforms than others, and it is not always clear whether an area is part of a channel or part of the floodplain. Also, some drainage lines run into lakes and then continue (drain from) across the lake. When such lakes or pans are small then the distinction between waterhole and basin (non-channel) may be harder to make. Useful guidelines for making the distinction are the depth and width of the feature with respect to the drainage line channel. Also, if the landform is clearly a result of the erosive action of water in the channel then it is a waterhole.

Drainage lines can be classified according to various landform attributes including:

- size of catchment;
- position in network – stream order;
- substrate – bedrock, loose rock, gravel, sand, clay, loam etc;
- gradient;
- channel depth;
- width (major & minor); and
- vegetation – both in channel and fringing.

If all the combinations of values for these attributes were set up as wetland types in a classification, it would be very large and unwieldy. Accordingly not all the above attributes of channels are directly incorporated in the classification for the arid NT. All these factors are still important in describing individual wetlands and the variation within a wetland type.

Many of the major rivers have distinct channels, with well defined banks, but are flanked by benches of perhaps a few hundred metres wide that are also well below the level of the main floodplain. They are typically dominated by Coolabahs (*Eucalyptus coolabah subsp. arida* in the south and *E. victrix* in the north) and would appear to function in some ways as swamps, filled with still or relatively slow moving water from over-bank flow from the main channel. However, they are also distinctly linear landforms, which presumably have linear flows of water along them at times when they become part of a broad flowing watercourse. Despite this, the distinction between basin and channel wetlands is useful in the arid NT.

Upland and Lowland Landforms

In the arid NT a distinction can be usefully made between upland and lowland landforms.

Upland watercourses are those descending from hills and mountains and typically have steeper gradients (but not necessarily steep), narrower channels and tend to have rockier substrates. They also tend to have fewer and smaller fringing trees, and where there are significant amounts of woody vegetation, it is often dominated by *Melaleuca* species. In contrast, watercourses in lowlands tend to be wider and typically have sandy beds, but may also have beds of clay, loam, bedrock, gravel or pebbles. Some lowland watercourses have coarse gravel or pebble substrates, where they travel between or emerge from rocky uplands. In general, lowland water courses are large and are lined by relatively tall trees dominated by *Eucalyptus* species; however, there are also some minor lowland channels, and some with no fringing woody vegetation.

There is no clear cut difference in stream gradient between lowland and upland but a dividing value of 5 degrees slope of the predominant channel gradient (over about 50 to 100 m) may be a useful guide, even though low gradient sections of upland watercourses occur, such as on plateaus.

The distinction between upland and lowland is less clear for plunge pools and other wetlands at or near the base of ranges, where drainage lines emerge from steep hills onto flatter terrain but which is variously rocky or undulating. An intermediate category could be created for these areas but is not done so here.

- Upland** - area of elevated and generally rocky terrain with high to moderate gradient drainage lines
- Lowland** - area of generally level terrain with low gradient drainage lines

Another distinction could be made for upland watercourses to distinguish those that are separated from the rest of a drainage network by waterfalls that are impassable to all or most fishes.

The distinction between upland and lowland basins (not within channels) can also be made but there are very few examples of upland wetland basins.

Water Depth and Landform

Water depth is an important influence on the ecological character of wetlands and particularly on longevity. The potential water depth is a function of landform while actual water depth also depends on hydrology. Although the terms 'deep' and 'shallow' are used widely in wetland literature, they are not always quantified (e.g. Williams 1998a & 1999) and there are no standard definitions. Boulton and Brock (1999) define shallow water as less than 1m in the context of stratification (layering by temperature). Similarly, Paijmans *et al.* 1985 give 1m as the maximum usual depth for swamps and lakes as 'deeper than 1m when full' (Paijmans *et al.* 1985, p.24). Other depth limits and guidelines have been used, such as a 6m limit set in the Ramsar classification for including marine waters as wetlands. Barson and Williams (1991) note that 2 metres is a common arbitrary depth limit used to exclude the deeper parts of channels from some definitions of wetlands. Similarly, Blackman *et al.* (1992) use 2 m as a depth limit to distinguish deepwater habitats from wetland habitats in permanent inland waters.

Additional Wetland Landform Terminology

The term floodout has wide colloquial usage in the arid NT for places where a drainage channel becomes indistinct or disappears completely, and water is dispersed across a plain or between dunes. They occur both at the final termination of a river system and at interim areas where channels diminish or disappear and then reform 'downstream'. In this sense floodouts are somewhat distinct from floodplains which occur adjacent to a continuing river channel. However, there are other more formal definitions of the term floodout, for description of broad landscape formation process (geomorphology):

'The alluvial plains that extend into the deserts are known as floodouts (Mabbutt 1977)'

The colloquial usage may differ somewhat from the geomorphological usage. For example, Patton *et al.* (1993) use the term to describe the plain over which the Ross River flooded in a 'paleo' or 'mega' flood.

Sections of rivers are often referred to as 'reaches'. Some major river channels disperse into multiple, smaller channels where low gradient and other factors reduce water speed. Such drainage patterns are called braided, anastomosing or reticulated. Knighton and Nanson (2000) provide a detailed definition of 'anastomosing'.

Paleodrainage features are subsurface drainage features where water flows in unconsolidated sediments that have filled in ancient valleys and watercourses, however, the term is sometimes used to refer to areas of very low gradient surface drainage with some relatively poorly defined surface channels. These include some areas of saline channels in the Tanami Desert.

The geomorphological term playa is commonly used in scientific discussions of wetlands and refers to 'flat topographic depressions that are occasionally flooded' (Williams 1998a, p.40). The waters and sediments may be fresh or saline and those that are saline are sometimes called 'salinas'. However, salina is also used for saline marshes (Moore 1968; The Macquarie Dictionary 1981) and so is avoided here. According to the Macquarie Dictionary, the floor of a playa may be sandy, salty or mud-caked, and examples of each were encountered in the arid NT. In addition, the floor may be variously stony; including closely packed gibber stones. Gibber surfaced playas are distinguishable from gibber plains in general by being a slight depression with a surface lower than the surrounding landscape. Gibber is a term used in central Australia to refer to generally flat land with surfaces of tightly packed pebbles, typically of dark colour and smooth and shiny. The formation of gibbers is summarised by Purdie (1984).

The related terms clay pan, salt pan and salt lake have more general (vernacular) use in the arid NT than 'playa'. 'Salt lake' is sometimes used only when water is present but other usages include saline playas in the wet or dry state. Likewise, the term saltpan may be used interchangeably with salt lake, or restricted to dry saline playas. If a playa is encountered when inundated or damp, any surface salt crust may be dissolved, making it a poor diagnostic feature. The terms 'saltpan' and 'claypan' are generally used where vegetation is sparse and this is how they are used in the descriptions of arid NT wetlands. Claypans are defined in the Macquarie Dictionary as 'a depression in the ground of hardened impervious clay which retains water'. The term pan also has a usage in soil science for impervious horizons (layers) of various composition other than rock, and often below the surface.

The terms 'waterhole' and 'rockhole' are often used interchangeably. Both terms are virtually always used for parts of intermittent watercourses where pools of deeper water persist, whether temporarily or permanently. 'Rockhole' is usually used for waterholes that are substantially or wholly confined by exposed bedrock, and in general usage can be considered a subcategory of waterholes. Rockholes may be in smaller elevated creeks in mountain ranges, at the base of ranges or in gorges where large rivers 'cut through' mountain ranges. Occasionally the term waterhole is used to describe a water pool within a swamp area rather than a section of a watercourse, but we have avoided that usage.

The term rockhole is also used for features that are not part of drainage channels.

The terms gorge and canyon are used quite loosely and interchangeably in central Australia and so are also treated as equivalent in this report.

5.4 Wetland Size as an Attribute of Wetland Type

The Ramsar classification uses 8 hectares as a distinction between what they call lakes and ponds. Eight hectares equates to a circular area with a diameter of 319m. Blackman *et al.* (1992) similarly use an 8 ha limit to distinguish 'palustrine systems' from 'lacustrine systems' (lakes); these being two of the five major systems in the upper level of their classification of Queensland wetlands. Palustrine is a limnological term for shallow freshwater wetlands and is defined in *A Dictionary of Ecology, Evolution and Systematics* (Lincoln *et al.* 1998) as 'marshy habitats'. The 8 ha limit has not been used as upper level determinant in the arid NT wetland classification. However, it has been incorporated at a lower level, to facilitate consistency with the Ramsar definition.

Various other size categories can be applied to classifying wetlands as discussed below.

The Semeniuk classification scheme, described in Finlayson (1999), defines five size categories of wetlands:

- megascale - very large - 10km x 10 km;
- macroscale - large - 1000m x 1000m;
- mesoscale - medium - 500m x 500m;
- microscale - small - 100m x 100m; and
- leptoscale - very small - < 100m x 100m.

These categories are a useful division of the range of wetland sizes in the arid NT but there has not been a need to incorporate them in the classification or adopt the generally unfamiliar terms (megascale etc).

There are various small wetlands listed in a Directory of Important Wetlands in Australia, including some of 1 hectare. Barson and Williams (1991, p.8) note that in a survey of Victorian wetlands, the 'greatest diversity of plant species was recorded from small shallow freshwater wetlands' and recommend that small wetlands, less than 1 ha, be included in surveys.

The Ramsar Convention Key Document from 1999, *Strategic framework for the List of Wetlands of International Importance* (internet site of Ramsar: key_guide_list_e.htm), encourages contracting parties to recognise that potential Ramsar sites are not necessarily the largest wetlands within their territory. 'Some wetland types either never were or are no longer found as large wetland systems' (item 40). Despite this, there is a natural bias towards large wetlands and wetland aggregations in the lists of national and internationally important wetlands (e.g. *A Directory of Important Wetlands in Australia*). This reflects the importance attached to waterbirds which require large breeding areas to maintain

population levels. However, the key document points out that small wetlands may also be important for waterbirds, especially as ‘staging posts’ along migratory routes.

Items 50 and 51 of the same Ramsar Key Document deal with protocols for Ramsar listing of clusters of small sites.

Although there is no formal size restriction on wetlands, there must be some lower size limit below which the term wetland is not useful. Based on this inventory, a lower limit in the order of 5 – 10 m² is suggested for the arid NT.

5.5 Water Regime as an Attribute of Wetland Type

Temporal variability is a defining characteristic of most arid NT wetlands, thus it is important to establish terminology with which to describe water regimes and to incorporate different water regimes into the classification and description of wetland types. In this section we discuss the factors that constitute water regime and ways in which they have been quantified in the past, before presenting a system for use in the arid NT.

Water regime incorporates several distinct factors relating to inundation, where ‘*inundation*’ is defined as the covering of the land surface by water:

- depth of inundation;
- area of inundation;
- duration of inundation;
- proportion of time the wetland is wet;
- frequency of inundation events;
- reliability of inundation;
- seasonality of inundation; and
- variability of inundation.

Other parameters may be useful indicators of inundation regime for wetlands for which inundation history is poorly known, including:

- maximum depth;
- longest known inundation; and
- number of times known to dry out.

For some small swamp wetlands or parts of wetlands, the water regime may sometimes involve soil saturation with barely any preceding inundation. Also, for some temporary wetlands, it may be appropriate to distinguish longevity of soil saturation from longevity of inundation, to properly characterise the longevity of wetland state as opposed to dryland state.

For some wetland types, inundation events vary widely through time such that they may relatively frequently have shallow, patchy and short lasting inundation, but are much less often filled at or near capacity.

The pattern of inundation and drying is a major influence on the biota of a wetland. Accordingly a consistent terminology is required for describing what can be called the ‘water regime’. Various terms and definitions have been proposed in the wetland literature but as yet few have become standard. The following discussion describes the range of regimes and the terminology used in this report.

Longevity and Frequency of Inundation

There are many factors that influence longevity of inundation including:

- permeability of the substrate;
- initial depth;
- rate of evaporation (time of year, temperature, humidity, wind and shading); and
- ongoing recharge from groundwater or subsequent rainfall.

In general, the larger and deeper the initial inundation, the longer it lasts.

Springs and waterholes in rivers, including rockholes in gorges, are the only natural wetlands in the arid NT for which some are permanent or nearly permanent. 'Permanent' waterholes are defined here as those that have not been known to go dry and all others are broadly referred to as 'non-permanent'. Even most of the permanent waterholes do experience some fluctuation in area and depth of water.

There is no standard terminology to distinguish various categories of non-permanent water, and naturally there is a continuum from quite short lived waters of weeks to a few months, through to those that last many years and are generally inundated to some degree. The same terminology for persistence of water can be applied to waterholes, springs, swamps and lakes; however, there are no permanent or semi-permanent swamps or lakes in the arid NT. Many springs vary in output through time and may produce running creeks at one extreme yet dwindle to seepages that only create locally saturated soil or subsoil. In such cases the stream created by the spring is not permanent while in some sense the spring itself may be. The term 'temporary' is often applied to all non-permanent wetlands; however, it may more usefully be used for wetlands that are generally dry as opposed to those that are generally wet. Various criteria could be chosen to more tightly define this. For example, 'generally wet' could be defined as wetlands that are inundated or saturated for at least 50% of the time (long-term average) and 'temporary' wetlands as those that are inundated or saturated for less than 50% of the time.

The most reliable, non-permanent waterholes and springs have only been known to dry up completely in major droughts; perhaps once or twice in the last century, and may be described as 'semi-permanent' or 'almost permanent'. These can be usefully distinguished from other 'generally wet' springs and waterholes that dry up more frequently but are nevertheless more often wet than dry. Unmack (2001a) categorised waterholes by how often they dry out completely, as part of a study of the persistence of fish in rivers of the southern part of the arid NT. He used the following categories:

- permanent – includes those known to dry 'occasionally';
- generally dries out once in 10 to 100 years; and
- generally dries out once in 1 to 9 years.

'Long lasting' waterbodies could be defined as those that are often dry but when inundated hold water for many months to several years. 'Medium lasting' waterbodies could be loosely defined as those that hold water for several months and 'brief' water bodies as those that last less than a month. There is insufficient data to warrant more detailed or tightly defined definitions.

The information available to assess the longevity of particular waterbodies is predominantly from people who have lived in an area for several decades; mostly pastoralists and Aborigines. In some cases there are written records. For a few of the larger waterbodies, useful information can be obtained from the historical collection of satellite based spectral scanners, with data from the past three decades (e.g. Roshier *et al.* 2001).

The 'Australian Soil and Land Survey Field Handbook' (McDonald *et al.* 1990) recommends the following categories for the frequency and duration of inundation.

Inundation:

- more than one occurrence per year;
- one occurrence in between 1 and 10 years;
- one occurrence in between 10 and 50 years;
- one occurrence in between 50 and 100 years;
- less than one occurrence per 100 years; and
- no inundation.

Duration:

- more than 120 days;
- between 20 and 120 days;
- between 1 and 20 days; and
- less than 1 day.

Pajmans *et al.* (1985, p.24) define the following classes for frequency of inundation in 'land subject to inundation':

- annual or more frequent flooding;
- inundation by 1 in 10 year event;
- inundation by 1 in 50 year event;
- inundation by 1 in 100 year event.

For lakes, Pajmans *et al.* (1985, p.6) define the terms '*permanent*', '*seasonal or intermittent*' and '*episodic*' in terms of the ratio between inflow and outflow, as follows:

- permanent lakes – annual inflow exceeds minimum annual loss in 90% of years;
- episodic lakes – annual inflow is less than the minimum annual loss in 90% of years;
- seasonal or intermittent lakes – those lakes between the above two extremes.

Williams (1985) classified temporary waters as predictably filled versus unpredictably filled and Williams (1998a, p.39) proposed the following definitions.

Permanent wetlands are those which normally contain water all and every year; water is absent infrequently (such as during severe droughts);

Temporary wetlands are those which are frequently dry; when dry, no surface water remains, or water persists only in remnant pools. Temporary wetlands comprise two types:

Intermittent...contain water or are dry at more or less predictable times in an annual cycle...

Episodic...contain water more or less unpredictably, not as part of an annual cycle.'

Notable aspects of the Williams (1998a) definitions are that: permanent wetlands may dry up occasionally; temporary wetlands are only divided into those with regular annual inundations and others; and intermittent is used for wetlands with a generally predictable annual cycle.

A more detailed classification of water regime was defined by Boulton and Brock (1999, p.150), who extended the water regime classification of Pajmans *et al.* (1985) as follows.

Permanent or near Permanent (perennial). Predictably filled although water levels may vary. Annual inflow exceeds minimum annual loss in 90% of years. During extreme drought these wetlands may dry. Much of their biota cannot tolerate desiccation.

Seasonal. Alternately wet and dry every year according to the season. Usually fills during the wet part of the year and dries predictably and annually. Surface water persists for months, long enough for some macroscopic plants and animals to complete the aquatic stages of their life cycles.

Intermittent. Alternatively wet and dry but less frequently and regularly than seasonal wetlands. Surface waters persist for months to years.

Episodic. Annual inflow is less than the minimum annual loss in 90% of years. Dry most of the time with rare and very irregular wet phases that may persist for months.

Ephemeral. Only filled after unpredictable rainfall and runoff. Surface water dries within days of filling and seldom supports macroscopic aquatic life.

Although this system combines permanent and near permanent it recognises that these are not the same thing. Also, Boulton and Brock (1999) reserve the term ephemeral for very short lived wetlands of a few days duration. Under our definition of a wetland (section 1), such 'empherally' wet areas are generally not wetlands as they rarely supports macroscopic wetland life. Regardless of the choice of terms, the recognition of finer classes by Boulton and Brock (1999) is meaningful and applicable to the survey data collected for the arid NT. Some adjustments to the definitions are warranted for use in the arid NT. There are several lakes that are generally dry and fill only episodically, but can remain wet for well over a year. Examples are Lake Lewis and Salt Creek (Fox) Lake with the recent inundation of Salt Creek Lake lasting for over two years. Also, many arid NT wetlands are inundated by unpredictable, episodic rain events, but more frequently than the above definition of episodic.

It is possible that additional categories or sub-categories could be useful extensions to the system of Boulton and Brock. Although there is generally a lack of systematically collected data on the inundation history of particular wetlands, a finer scale classification would meaningfully reflect the range of inundation regimes that occur, even though many wetlands could not be designated to a single category.

There are very few if any ‘seasonal’ temporary wetlands in the arid NT. However, there is anecdotal evidence that those in the north of the study area are generally more frequently filled than those further south and inundation events are usually associated with monsoon rain systems extending inland from the northern coast of the continent.

The categories of inundation frequency and duration used to describe arid NT wetlands in this inventory are as follows, and are an adaptation and extension of some of those described above.

Water Regime Categories for Describing Arid NT Wetlands and Defining Types

Long-term (Generally Wet) Wetlands
inundated or saturated at least 80% of the time and typically for longer than 1 year at a time; subdivided on incidence (frequency) of drying out as follows

- Permanent** - not known to ever completely dry out
- Semi-Permanent** - only dries out in the most severe droughts, in the order of once in 50 years or less frequently
- Rarely Dry** - usually inundated but dries more frequently than semi-permanent in the order of once in 10 to 40 years
- Occasionally Dry** - usually inundated but dries out several times a decade more frequently than once in 10 years

Temporary Wetlands
inundated or saturated less than 80% of the time, and sub-divided on frequency, seasonality and on duration of inundation as follows

Frequency of Inundation:

- Near Seasonal** - inundation is mainly from the summer monsoon but not every year in the order of 1 in every 2 years to 1 in every 5 years
- Frequent but Intermittent** - inundation is relatively common, in the order of 1 in 2 years to 1 in 5 years, but not strongly associated with the summer monsoon
- Rare and Intermittent** - inundation is relatively rare, in the order of 1 in 10 years
- Episodically Rare** - inundation is rare, in the order of 1 in 20 years

Duration of Inundation (in temporary wetlands):

- Long Lasting** - more than 6 months and up to several years
- Medium** - between 1 and 6 months
- Brief** - lasts less than 1 month

Note that duration categories above are based on a wetland being initially full.

Most of the terms defined above are used for describing individual wetlands, where the relevant information is available, and not as delineators of wetland types in the classification.

If there were good data on the longevity of individual wetlands it is expected that there would be few of intermediate longevity with most being wet for less than about 20% of the time (temporary) and a few being wet for more than about 80% (long-term). Most of those at the long-lasting end of the longevity spectrum rely on groundwater for their longevity but size and shading may be sufficient to sustain some. Those at the other end of the spectrum are mostly filled by episodic large rainfall events, however,

smaller rainfall events also produce wetland conditions, although often not enough to fill large basins. There are no doubt some wetlands that are intermediate in the longevity spectrum (e.g. wet around 30% to 80% of the time); mainly springs, large shaded rockholes without spring feed and some of the near-seasonal waterholes in the north of the study area.

The ecological character of some wetlands can vary dramatically with different states of inundation and time since the last inundation. For example, an area may be dry, a vegetated swamp or open water depending on the water level. Variation in water levels can also correspond with changes in salinity such as salt lakes which can change from slightly saline to highly saline as salt lake waters evaporate. When assigning a wetland to a wetland type it is necessary to choose a particular state of inundation as characteristic. The various other wetland types that the wetland can manifest are then listed in the description of the wetland.

Flow Volume in Springs

Springs can be categorised according to the volume or rate of flow which is important influence on the size of the associated wetlands and their vegetation. Various other factors may be used to classify springs including the geology of the water source and the landform of the outflow area, including the size of the zone of emergence.

For the classification of arid NT wetlands two broad categories of flow type are distinguished:

Running Springs; and

Minor Springs and Seepages.

Further subdivisions are incorporated into the classification based on longevity (reliability) as well as landform and salinity.

No precise definitions have been formulated to quantify the flow volumes of the above classes. Measurement of flow is often not straightforward and accurate measurement requires either natural waterfalls or artificially constructed gauges such as V notches. Even the estimate of flow depends on exposed bed rock where all or most water flows on the surface. Running Springs are loosely defined as those with surface water output greater than about 0.5 litres per second, which in rocky terrain is sufficient to produce flowing water in small channels. Anything less than this is considered a minor spring or seepage. This category includes soaks where there is no surface flow; only saturated soil at or near the surface. It may also include springs with discharge rates exceeding 0.5 litres per second, but which have little if any surface flow due to porous soils (e.g. sand) at a dispersed zone of emergence,.

Guidelines for very rough estimates of flow rates are given below (provided by R.Read *in.litt.*):

- 0.1 L/s is a slow running garden hose;
- 0.2 L/s is a fast garden hose; and
- 1 L/s is 55 mm over a V-notch.

Limnological Terms for Categorising Aquatic Environments

The study of inland or freshwater ecology (limnology) has traditionally distinguished flowing water (lotic) from still water (standing, lentic) and separated lake environments (lacustrine) from broad, shallow waters and waterlogged areas (palustrine). In the arid NT these distinctions are more useful for describing the ecological function of individual wetlands than for general classification; partly due to the high proportion of temporary wetlands compared to regions with higher and more predictable rainfall. For example, none of the rivers are permanent and accordingly their wetland character changes through time, having dry, flowing or standing water of changing depth and quality. However, there are some permanent, small spring fed creeks and permanent riverine pools to which the above limnological terms can be more readily applied. The discipline of limnology also recognises types of aquatic environment based on the aquatic invertebrate fauna and micro flora and the related physical and chemical attributes of the water (Barson & Williams 1991, and Boulton and Brock 1999). These categories may apply to entire wetlands such as types of lake (e.g. amictic, holomictic and meromictic depending on degree of water

mixing), or to parts of wetlands, such as the shore and adjacent parts of the lake or river bed (littoral zone), the river and lake beds (benthic), open water areas away from the bottom and shore (limnetic), areas of fast shallow water (riffles), and the vertical zones within deeper waters, based on temperature (epilimnion, metalimnion & hypolimnion) and penetration of light (euphotic & profundal). Some arid NT wetlands are significantly deep and may be usefully described using the above terms. For example, some permanent waterholes are in the order of 15m deep and the longer lasting temporary lakes in the order of 5 to 10m deep. A useful introduction to limnology in Australia can be found in Boulton and Brock (1999) with a good glossary of terminology.

5.6 Wetland Salinity and Water Chemistry as Attributes of Wetland Type

Inland waters are often broadly referred to as 'freshwater' due to a traditional distinction between marine (saline) aquatic environments and non-marine ones. However, in Australia, the relative abundance of saline inland waters, up to and exceeding the salinity of sea water, makes the term 'freshwater' inappropriate as a general descriptor of inland wetlands.

The salinity of a wetland is a major determinant of the types of plants and aquatic animals that can live in it. It is therefore appropriate that it is included as one of the major determinants of wetland type. Various terms are used to describe different concentrations of salinity, such as fresh, brackish, semi-saline, saline, hyper-saline and hypo-saline, but they are not universally defined. Also, there are various different ways of measuring and recording salinity. A brief summary is given here to assist with the interpretation and application of these terms in classifying and describing arid NT wetlands.

Salinity refers to the amount of dissolved salts in water. Inorganic solids that readily dissolve in water are called salts and separate into positively charged cations and negatively charged anions. In surface waters, typical cations are calcium, magnesium, sodium and potassium; and typical anions are carbonate, sulfate and chloride (Blackman *et al.* 1992). Sodium chloride is typically dominant in Australian waters but calcium and magnesium carbonates (CaCO_3 & MgCO_3) are important in some areas (Boulton & Brock 1999). Gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$; a hydrated form of calcium sulphate) is a significant salt in some saline wetlands in the arid NT such as Lake Lewis (English *et al.* 2001). Areas high in calcium carbonate (CaCO_3) are described as 'calcareous'. Sources of salts in wetland waters include the water that enters the wetland, dust and rain, and salt stored in the wetland in soil and as crusts on the surface of dried wetlands. Runoff entering a wetland can contain salts dissolved from soil and rocks. In the arid NT, some sections of rivers, salt lakes, saline swamps and some riverine waterholes are saline due to the discharge of saline aquifers directly into them.

One way of measuring salinity in water is the proportion of dissolved solids measured by weight, called the 'total dissolved solids' (TDS). This is worked out by evaporating a standard volume of the water (H_2O) and weighing the residue and is simple but time consuming (see Boulton & Brock 1999 for a standard method). Units for expressing TDS are commonly grams per litre (gL^{-1} or g/L), parts per thousand (ppt; = gL^{-1}) and milligrams per litre or parts per million (ppm). Parts per thousand is also sometimes expressed using the ‰ symbol similar to the percent symbol. Boulton and Brock (1999) warn against confusion between the commonly used term 'total dissolved solids' (defined as all solids that pass a 10 μm filter) and the less common 'total dissolved salts' both of which are abbreviated to TDS. Here, TDS is used only for 'total dissolved solids'. Where there is a significant organic fraction in TDS it is not so strongly related to salinity.

Another way of measuring salinity is electrical conductivity, which is readily measured with a conductivity metre. Salts dissociate in water, into positively charged cations and negatively charged anions. An increased density of cations and anions in a solution increases its conductivity, typically expressed in units of milli siemens per cm (mS/cm) and micro siemens per cm ($\mu\text{S/cm}$) at a temperature of 25°C. Units of $\mu\text{S/cm}$ are equivalent to electrical conductivity units (EC). Conductivity can be accurately measured far more quickly than TDS but the relationship between TDS and conductivity varies with the composition of the salts present and the temperature of the water and other aspects of the water's chemistry such as the presence of conductive organic acids. An introduction to measuring conductivity and wetland chemistry in general can be found in (Boulton & Brock 1999).

The relationship between conductivity and total dissolved solids is not constant, but a useful approximation is [$1\mu\text{S}/\text{cm} = 0.65 \text{ ppm TDS}$] and inversely [$1 \text{ ppm} = 1.54\mu\text{S}/\text{cm}$] for typical groundwater.

A more accurate equation has been fitted to data from 316 central Australian ground water analyses (R.Read *in. litt.*):

$$\text{TDS} = -26 + 0.62562 \text{ EC} + 0.000006786391568 (\text{EC})^2 \quad [\text{equation 1}]$$

This equation is valid from about 300 to 30 000 EC.

In a review of wetlands of south-west Queensland, Jaensch (1999) recognised only two categories of wetland salinity – fresh and saline; saline wetlands being those with more than 1 g/L (1000 ppm) TDS; equating to a conductivity of approximately 1600 $\mu\text{S}/\text{cm}$. In contrast, Williams (1998a) gives 3 g/L TDS (3000 ppm) or greater as a standard definition for saline wetlands, which equates to a conductivity of approximately 4600 $\mu\text{S}/\text{cm}$.

More detailed categories are recommended by various authors. Semeniuk (1987, cited in Barson & Williams 1991) has 6 categories of concentration of water salinity: fresh, subsaline, hyposaline, mesosaline, hypersaline and brine. Blackman *et al.* (1992) also recognise six categories, but with different terms, as shown in table 9, and Lothian and Williams (1988) define four categories. In the arid NT there are difficulties in applying such a detailed break down because the salinity of most wetlands changes through cycles of wetting and drying and many wetlands are dry when surveyed. The salinity of dry wetlands can be measured as soil salinity, based on conductivity of a standard solution of soil in demineralised water. However, the relationship between soil salinity and surface water salinity of a wetland is poorly known, so it is not appropriate to include detailed categories of wetland salinity in the classification of arid NT wetlands. A broad distinction between fresh and saline is certainly warranted, and more detailed categories can be used in describing individual wetlands.

Table 9. Water salinity categories recognised by Blackman *et al.* (1992)

Category	Sub-category	Total Dissolved Solids (tds)		approximate conductivity (derived here using equation 1)	
		parts per thousand (% = g/L)	parts per million (ppm)	micro Siemens ($\mu\text{S}/\text{cm}$)	milli Siemens (mS/cm)
Fresh		< 0.5	<500	<800	<0.8
Mixosaline (brackish)	Oligosaline	0.5 – 5	500 – 5000	800 – 7,500	0.8 – 7.5
	Mesosaline	5 – 18	5000 - 18,000	7,500 – 23,000	7.5 – 23
	Polysaline	18 – 30	18,000 - 30,000	23000 – 35000 *	23 – 35 *
Eusaline		30 – 40	30,000 - 40,000	35000 * - 44,000*	35* – 44*
Hypersaline		>40	>40,000	> 44,000 *	> 44*

* those conductivity estimates marked with an asterisk are made by extrapolating beyond the range in the data used to create equation 1.

Hypersaline is sometimes used for water that is more saline than seawater (e.g. Lincoln *et al.* 1998). In their overview paper on Australian biodiversity, Mummery and Hardy (1994) define highly saline salt lakes as having greater than 50 ppt TDS (50,000 ppm).

The term brackish has wide usage for slightly saline waters; however, Williams (1998a) recommends that the term brackish be only used for mixtures of fresh water and sea water, and accordingly we discourage its use in the arid NT. Instead, the term ‘semi-saline’ is recommended for wetlands that have salinities approaching but not exceeding the chosen limit for saline.

Seawater is often used as a reference for comparing the salinities of inland waters. Other useful comparisons are the maximum salinities for human consumption, stock and irrigation use are given in table 10 along with threshold values for saline and semi-saline as used in the classification of arid NT wetlands.

Table 10. Useful reference values of salinity

Description	Total Dissolved Solids (ppm)	Conductivity in micro Siemens ($\mu\text{S}/\text{cm}$)
World Average Seawater	35,000 (a)	53,000 (c)
Upper Limit for Stock	4000 – 5000 (b)	<i>6,040 – 7,430</i>
Limits for Horticultural Irrigation	550 – 6,600 (c)	1000 – 12,000 (c)
Threshold Value for Saline Wetlands following Williams (1998)	> 3000	<i>> 4600</i>
Threshold Value for Semi-saline Wetlands (saline wetlands according to Jaensch (1999))	> 1000	<i>> 1,600</i>
Human consumption (taste threshold)	400 (b)	< 680

Values compiled from various sources including those listed in the table plus: (a) Boulton & Brock 1999; (b) *Is the water Safe to Drink?*, a pamphlet by the NT Department of Lands Planning and Environment; and (c) Pamphlet: *Salinity, Conductivity and TDS Total Dissolved Solids* by Perth Scientific Equipment (c). Values are in italics were derived using equation 1.

We have followed Williams in defining ‘*saline wetlands*’ as those with salinities exceeding 3000 ppm TDS. We further define ‘*semi-saline*’ as salinity exceeding 1000 ppm but note that salt concentrations above 500 ppm may affect the biota, with 500 ppm being the upper limit for freshwater in the classification system of Blackman *et al.* (1992).

In some contexts the constancy or otherwise of salinity levels is an important factor of wetland ecology and is incorporated into classification (Barson & Williams 1991) using the terms stasohaline meaning constant salinity, and poikilohaline meaning changing salinity. However, this differentiation is less meaningful for temporary wetlands than permanent ones, since most temporary wetlands are poikilohaline.

The acidity or alkalinity of a wetland can also be important in ecological function, but is not often a critical component of classification. Blackman *et al.* (1992) recognise three categories for pH in water: acid (<5.5), circumneutral (5.5-7.4) and alkaline (>7.4). The range of water pH values recorded in the 2000-2001 arid NT wetlands survey was 4.2 to 9.6; however, most sites had relatively neutral water pH values of between 6 and 8.

pH has not been used in the arid NT classification because: it may vary diurnally with biochemical activity in the water as well as variation through cycles of temporary inundation; it is relatively difficult to consistently measure; and the relationship to the biota is poorly known.

It is not clear the degree to which the level of salinity controls whether a saline basin is vegetated, and therefore a swamp in our classification, or bare and classed a salt lake. Non-saline playas (claypans) are also largely unvegetated so salinity is not the sole cause of sparse vegetation. Other factors include soil structure and inundation regime as well as other factors of soil chemistry.

5.7 Vegetation as an Attribute of Wetland Type

Wetland vegetation is commonly used in classifying wetland types. This is appropriate since the vegetation is one of the most readily observable features of a wetland, especially for temporary wetlands, and vegetation is generally strongly influenced by both the inundation regime and the water chemistry, which can be hard to measure. Also, the vegetation can be an important determinant of habitat value of a wetland for animals.

Numerous systems for classifying vegetation exist based most often on the structure (height and density), the growth-form and longevity of species and the mix of species (floristic composition). A general

review of vegetation classification is not relevant here. A review of types of wetland plants, their relationship to water regimes and use in delineating and mapping wetlands is given in chapter 9 on wetland plant species. The possibilities for numerical classification of wetland vegetation in the arid NT is also discussed in chapter 9.

Pajmans *et al.* (1985, p.21) observe that ‘Classification of wetlands is a particularly difficult matter because not only do wetland types grade into each other but they may change through time either cyclically or irregularly’. Many wetlands contain several vegetation types which may correspond to different wetland types or alternatively may be incorporated into a single wetland type. As well as varying across a wetland, the vegetation may also change through time in response to drought, inundation, fire and grazing.

Important terms and categories of vegetation structure and species life-forms are defined here, as used in the description of arid NT wetlands and wetland types (they are repeated in chapter 9 in the overview of wetland plant species).

The longevity of plants is described in terms of ‘*annuals*’ and ‘*perennials*’. Annual plants are those which usually live for only one year before dying with subsequent regeneration from seed. Those that live longer are perennial and can be divided into ‘*short lived*’ (2-3 years) and ‘*long-lived*’. Important growth form characteristics for wetland classification are defined here, but many others exist. Woody plants are those that have woody stems or trunks and are all perennial. Trees are tall woody plants and where they dominate the vegetation structure, the term ‘*wooded*’ is used to describe a wetland. This is loose adaptation of the term ‘woodland’ as defined by Specht (Specht *et al.* 1995). A ‘*tree*’ is defined here as:

tall woody plants that grow to taller than 2 m; typically with one or few dominant trunks with major branches well above the base. A single species of palm is included in this group although palm stems are more pithy than woody.

Shrubs are typically smaller than trees, however Coolabah trees (*Eucalyptus coolabah subsp. arida* & *Eucalyptus victrix*) can form very low woodlands of only 2 – 4 metres, even when several decades old. In contrast, some Acacia species can grow as tall shrubs and sometimes as trees, such as Mulga (*Acacia aneura*). A ‘*shrub*’ is defined here as:

woody plants that are smaller than trees and mallees, generally with multiple branches from the lower stem.

The distinction between shrubs and non-woody plants is not always straightforward. An intermediate category called ‘*sub-shrub*’ is defined here as:

semi-woody plants that are intermediate between shrubs and forbs - generally smaller than 1m tall and somewhat woody at the base but herbaceous above.

All non-woody plants are ‘*herbs*’; a term which includes grasses, sedges, rushes, ferns and forbs (dicotyledenous herbs). Gramineous herbs or graminoids are a sub-group of herbs which are grasses or grass like and includes sedges and rushes.

Another growth form that is characteristic in some wetlands is succulence. Succulent plants have stems and/or leaves which are fleshy and have a very high moisture content.

‘*Swamps*’ are defined here as a broad wetland type, based on the presence of emergent vegetation. Various wetland types are defined as sub-categories of ‘*swamp*’ based on vegetation structure and on the plant species and groups of plants that are common structural dominants. As discussed in the section of spatial arrangement and scale, Blackman *et al.* (1992) apply a 30% limit to the amount of areal coverage of emergent vegetation in a basin to distinguish ‘lacustrine’ wetlands (lakes) from ‘palustrine’ wetlands (swamps) in areas greater than 8 hectares. No analysis has been undertaken to test the applicability of this in the arid NT, however, a threshold value of 30% is probably too high. Further clarification should determine whether projective foliage cover or canopy extent is the better measurement of cover for this purpose. Another factor in determining whether a wetland is a swamp is whether the vegetation is emergent in the main or largest zone or sub-habitat. Where there is dense emergent vegetation but only in a minority of the wetland area, it may not be appropriate to classify the whole wetland as a swamp.

An important consideration and complication in classifying wetlands as swamps is that vegetation may be totally covered in big inundations, such that the wetland functions as a lake or pool for a period. If the vegetation is only covered for a few weeks, the wetland is best classified as a swamp, but if it is for a

medium to long period, then the area might be best classified as a lake. The vegetation of some swamps is short lived and only develops as water levels drop. Some non-perennial plant species mainly grow in wet soil following complete loss of free surface water. Such species may temporarily form the dominant vegetation of a wetland and can be an important part of its total ecological character and conservation significance. In applying the classification of arid NT wetlands, such temporarily vegetated wetlands are treated as swamps, even though the vegetation is neither perennial nor emergent. Accordingly the definition of 'swamp' is extended as follows.

Swamp - a wetland in which emergent or post-inundation vegetation strongly influences the ecological character across the general extent of the wetland

In our survey, many floristic variations were encountered between wetlands with the same structural dominance. However, it was generally impossible to distinguish the possible causes which will include differences in recent inundation history, variations in soils, differences in long-term inundation regime and differences in recent and long-term cattle grazing history. Accordingly, annual vegetation species were generally avoided as determinants of wetland types. The importance placed on post-inundation annuals in defining some wetlands as swamps is the main exception.

When inundation is also particularly long-lasting, the perennial vegetation may also be killed. Thus, an area may have emergent vegetation in some inundation events and not in others. The sometimes complex succession patterns in wetland vegetation and variations in inundation depth can make it difficult to determine what is the dominant ecological character of a wetland and consequently which wetland type best summarises it. This issue is discussed further in the following discussion of the classification developed for the arid NT.

5.8 Spatial Arrangement and Wetland Type

Wetlands come in many shapes and sizes and spatial arrangements. Some wetlands have complex patterns of landform, substrate, hydrology and vegetation within them. A clearly defined system is necessary for delineating and naming wetlands, recognising their connectedness to other wetlands and recording information about the variation within them.

Here we discuss and present terminology for describing various spatial arrangements. This includes the arrangement of wetland environments with respect to the surrounding drylands. It also includes spatial patterns within wetlands. Spatial terminology is not used to define wetland types but is relevant in applying them and for describing the character of a wetland.

Defining Wetland Boundaries

Some wetlands are easily recognisable as distinct units in the landscape due to either (or both):

- the uniformity (homogeneity) of the environment within the wetland boundary; and
- the contrast to adjacent non-wetland environments.

Even where the exact boundary is hard to define, as is often the case (Pressey & Adam 1995), an area may be readily described as a distinct wetland. However, in some places there may be no obvious single wetland due to either (or both):

- the presence of a variety of distinctly different wetland types; and/or
- a pattern of geographically close and connected wetland areas interspersed with dryland areas.

Blackman *et al.* (1992) suggest terminology for dealing with this, describing wetlands as 'continuous' or 'disjunct'. We suggest an alternative terminology: '*discrete*' or '*discontinuous*'. Discrete wetlands consist of a discrete area of land, which can be mapped as a single polygon, within which all or nearly all the area is wetland. Discontinuous wetlands consist of connected wetland areas interspersed with dryland.

Wetland Aggregations

A group of wetlands that are separated from each other but share some geographic proximity and commonality of wetland character can be considered a wetland aggregation. This is an important concept allowing the broad description of a group of wetlands, where there is insufficient information to describe each individual wetland.

Separate wetlands may share landforms at various scales, such as being part of the same floodplain, the same drainage system (catchment) or the same mountain range system. The term '**aggregation**' is used here to refer to set of distinct wetlands of the same broad type that have some such connection and are geographically close. The scale at which they are deemed to be close is not defined here.

The term 'aggregation' is also used in *A Directory of Important Wetland in Australia* (Environment Australia 2001). The boundary of an aggregation can be mapped, even when individual wetlands within it are not mapped.

Blackman *et al.* (1992) describe a detailed coding system for wetlands, which takes into account aggregations. Mapping of wetlands in the arid NT has not yet progressed to a level of detail where such a system is required.

Variation Within a Wetland and the Identification of Zones

The classification created for arid NT wetlands is designed for application at a broad scale in order to usefully group wetlands into recognisable types. In practice this is very difficult, as many wetlands incorporate a variety of environments. Thus, a single wetland may contain distinct areas corresponding to different wetland types. This is especially so when vegetation characteristics, such as structural dominance, distinguish different wetland types.

The physical environment may change gradually across a wetland (a gradient), or changes may be relatively sudden. Where changes are relatively sudden, it is quite straightforward to delineate distinct zones within a wetland. The vegetation generally provides a useful way of sub-dividing a wetland into zones during field survey. In our survey, zones were also referred to as 'sub-habitats'. In some cases, the zones correspond well to wetland types defined in the classification, whilst other zones are at a finer scale of distinguishing vegetation and other differences.

Blackman *et al.* (1992) defines terminology for determining when the character of a wetland corresponds to a single wetland type (simple wetlands) or some combination of types (complex wetlands). We have not adopted that terminology since a wetland that corresponds to a single 'wetland type' may nevertheless have complex variations in vegetation and hydrology among other things. We propose an alternative terminology for describing arid NT wetlands.

Wetlands can be divided into '**uniform wetlands**' and '**multi-type wetlands**', based on uniformity within the wetland area. Uniform wetlands are those where the ecological character is relatively uniform and should therefore correspond to one or two wetland types.

Multi-type wetlands have a relatively heterogeneous ecological character. Typically there are distinct areas within the wetland that correspond to separate wetland types, but often with areas of intergrading types.

The distinction between uniform and multi-type is very much influenced by the scale at which an area is considered and the detail of the classification. Most wetlands have some variation within them with the edges often being distinct and sometimes being ecotonal with the surrounding drylands. For example, many claypans have fringing tea-tree or Coolabah vegetation. These are mostly regarded as uniform, where the major part of the wetland is the bare claypan. In this example, the 'dominant' type equates to the type with the biggest extent.

In practice, very few individual wetlands were described to this detail in this inventory of the arid NT.

5.9 The Wetland Classification for the Arid NT

Creation of the classification

Prior to survey work for the arid NT wetland inventory, a preliminary (a priori) classification was constructed based on the pre-existing understanding of the wetland environments. This 'working classification' incorporated information from various local biologists. It also took into account the wetland types of south-west Queensland (Jaensch 1999) and advice from Roger Jaensch of Wetlands International, who was engaged as a consultant to assist with refining the inventory methodology. Observations during a preliminary field trip in July 2000 were also incorporated into a second iteration of the working classification which was then used and tested during the main period of survey work in 2000 and 2001. The working classification is presented in appendix 8 and uses landform as the primary attribute, following Semeniuk (1987 as cited in Finlayson 1999), with a division of landform into basins, channels and flats.

Following the main survey program in 2001, the working classification was further revised to create the classification presented below. The classification does not follow a purely hierarchical approach due to the variety of environmental attributes that have an important influence on the general character and ecological function of arid NT wetlands.

Overview of the Classification

The classification of arid NT wetlands is based on defining easily recognisable wetland types. There are 71 wetland types defined, including some for which there is very little information, but which nevertheless have a distinctive ecological character. Although this classification is detailed compared to many others, it is designed so that it can be used at various, levels, depending on the purpose. The full list of 71 types may not be required for many purposes but illustrates the variety of wetland types that exist.

The 71 wetland types are classified into six groups based on major landform, hydrological function and origin:

- basins (17 types);
- flats (4 types);
- channels (21 types);
- springs (18 types);
- subterranean (1 types); and
- artificial (10 types).

Below this level, other, semi-hierarchical divisions of the groups are made, but using different attributes for different groups. The order of the subdivisions is designed to assist in reporting the number and area of wetlands at various levels in the classification since many mapped wetlands are inadequately documented and cannot be allocated to specific wetland types. In this document, those classification categories at a higher level than the wetland type are referred to as 'broad types' regardless of hierarchical level.

Basins are subdivided based on predominance of vegetation: swamps vs. predominantly bare pans and lakes. These are further sub-divided on salinity and vegetation type. A size delimiter dividing large (> 8 ha) open freshwater bodies from smaller ones (< 8 ha) is included to allow reporting by Ramsar types.

Flats are subdivided on vegetation type.

Artificial wetlands are subdivided on source of water.

Channels are subdivided into upland vs. lowland and persistent pools vs. rest of channel.

Springs are subdivided on salinity, the surrounding landform, persistence and volume of flow.

The list of types is presented below in a way that shows the hierarchy and gives a brief definition of each type. Broader level wetland types are presented in bold aerial font; e.g. **Open Water Basins**. Wetland types are presented in ‘comic sans ms’ font e.g. **Highly Saline Lakes (Salt Lakes)**. The wetland types are the finest level of subdivision considered appropriate for the reconnaissance level inventory. Finer distinctions may be made within types but these generally have less (or undetermined) influence on plants and animals. The number of levels or subdivisions between a wetland type and the upper level (Basin/Flat/Watercourse/-Spring/Artificial) is not consistent. An alpha-numeric numbering scheme is used so that individual wetlands can be coded for wetland type. Where there is no subdivision at a level in the classification, a zero is used, so that all wetland types have a letter code (upper level: B/F/WU/WL/S/A) followed by four numbers. An extra level is included for water courses and springs. WU is used to code all upland watercourse wetland types and WL is used for the lowland ones. Likewise springs and seepages are subdivided into saline springs (SS) and freshwater springs (SF). Many of the identifiable categories of water regime and spatial arrangement are not used in defining these wetland types of the arid NT. This is to prevent the classification becoming unwieldy and difficult to communicate due to too many wetland types. Some aspects of water regime have a great influence on the plants and animals present and so have been incorporated in distinguishing wetland types. The categories of water regime and spatial arrangement that were defined in the preceding sub-sections can all be used as additional descriptors or modifiers of wetland type. For springs, the number and detail of wetland types defined exceeds the level of documented knowledge but is intended to accommodate expected differences in plant and animal life (between types).

More detailed descriptions of types and examples are given in the following chapter. Much of the rationale for the divisions and the definitions of the terms used are given in the preceding sub-sections. The Ramsar wetland types to which arid NT types equate are given in appendix Table 11 at the end of this chapter. Often there is not a one to one correspondence between Ramsar types and arid NT types.

List of Wetland Types

1. BASINS – FORMING NATURAL WETLANDS

(all inundation is temporary)

B1 Open Water Basins (sparse or no emergent vegetation when full)

B1.1 Saline Open Water Basins (salt lakes, salt pans and saline swamps)

B1.1.1 Saline Basins with Predominantly Unvegetated Bed

(predominantly unvegetated when dry)

B1111 Highly Saline Lakes (Salt Lakes)

Predominantly unvegetated and forming some surface salt crust when surface is dry. Crusting is variable from strong to thin and patchy. Includes gypsum lakes and pans.

B1.1.2 Saline Basins with Predominantly Vegetated Bed

(predominantly vegetated when dry – saline swamp – low vegetation which is covered when full)

B1121 Saline Lakes / Samphire Swamps

Halosarcia species dominate.

B1122 Saline Lakes / Non-Samphire Chenopod Swamps

Atriplex species usually dominate and occurs in waterbodies/zones of relatively low salinity (semi-saline).

B1.2 Open Freshwater Basins

(freshwater lakes and pans - may form herb swamps following recession of water and may include some shrubby swamps if shrubs are covered in exceptionally deep inundations; also includes isolated rockholes)

B1.2.1 Large Open Freshwater Basins (> 8 ha)

B1211 Large Freshwater Lakes and Pans

Larger than 8 ha. Includes clay pans, stony pans and deeper freshwater lakes and areas that form herbfields when waters recede. Clay pans may be predominantly bare when dry. They may be fringed by Coolabah Trees. Pans with patchy Swamp Cane grass are included in this wetland type.

B1.2.2 Small Open Freshwater Basins (< 8 ha)

B1221 Small Freshwater Lakes and Pans

Smaller than 8 ha. Including claypans with patchy Swamp Cane grass and those with stony beds (stony pans). Includes areas that form herbfields when waters recede.

B1222 Isolated Rock Holes

Rockholes not associated with drainage lines and are accordingly filled from local runoff. Include gnamma holes

B2 Swamps: Water Basins with Emergent Vegetation

(when full, emergent vegetation dominates character, or wetland state may be typified by saturated soil rather than inundation)

B2.1 Saline and Semi-saline Swamps (Saline Water Basins with Emergent Vegetation)

(vegetation emergent when full; wetland state may be typified by saturated soil rather than inundation)

B2.1.1 Shrubby Saline Swamps (includes semi-woody sub-shrubs)

B2111 Samphire Saline Swamps

Halosarcia species dominate. Often impossible to separate from saline lakes with vegetated floor, unless good information on inundation depths is available.

B2112 Non-Samphire Chenopod Saline Swamps

Atriplex species usually dominate. Occurs in waterbodies/zones of relatively low salinity (semi-saline). Often impossible to separate from saline lakes with vegetated, samphire swamp floor, unless good information on inundation depth is available.

B2.1.2 Grassy Saline Swamps

B2121 Saline Grassy Swamp

Salt tolerant grasses dominate; typically in waterbodies/zones of relatively low salinity (semi-saline). Often impossible to separate from saline lakes with vegetated, samphire swamp floor, unless good information on inundation depth is available.

B2.2 Fresh Water Swamps (Freshwater Basins with Emergent Vegetation)

B2.2.1 Wooded Swamps

B2211 Wooded Swamps (Non-linear)

Can be subdivided by dominant woody species, density of overstorey and nature of understorey. Overstorey is typically dominated by Coolabah species (*Eucalyptus victrix* or *Eucalyptus coolabah* subsp. *arida*) and occasionally by River Red Gum (*Eucalyptus camaldulensis*).

B2212 Wooded Swamps (Linear/Riverine)

Typically adjacent to major drainage lines and sometimes carrying water flows as an extension of the main channel. Also includes some minor drainage lines with no obvious channels. Overstorey is typically dominated by Coolabah species (*Eucalyptus victrix* or *Eucalyptus coolabah* subsp. *arida*)

B2.2.2 Shrubby Freshwater Swamps

B2221 Bluebush Swamps

Dominated by Northern Bluebush (*Chenopodium auricomum*) and may have scattered Coolabah trees (*Eucalyptus victrix* or *Eucalyptus coolabah* subsp. *arida*).

B2222 Lignum Swamps

Dominated by Lignum (*Muehlenbeckia florulenta*).

B2223 Other Shrubby Freshwater Swamps

Includes swamps dominated by *Acacia* species, *Melaleuca* species and *Chenopodium nitrariaceum* which somewhat resembles Northern bluebush.

B2.2.3 Other Vegetated (non-woody) Freshwater Swamps

B2231 Grassy Freshwater Swamps

Vegetation is dominated by grass species, generally perennials. Predominantly bare claypans with clumps of Swamp Cane grass (*Eragrostis australasicus*) are not included.

B2232 Herbaceous Swamps (non-grassy)

Depending on the typical inundation depth this category may be synonymous with open water bodies. It includes swamps dominated by low herbs, including Nardoo (*Marsilea* spp.) and also tall annuals such as Verbena (*Cullen australasicum* & *Cullen cinereum*) swamps and Budda Pea (*Aeschynomene indica*) swamps.

2. FLATS

Flats associated with floodplains and floodouts. When present, water is generally flowing in a consistent direction, even if slowly and inundation is generally short lasting.

- F0001 Bare Flood-prone Flat
- F0002 Wooded Flood-prone Flat
- F0003 Shrubby Flood-prone Flat
- F0004 Grassy Flood-prone Flat

3. WATER COURSES

The distinction between upland and lowland is not always clear-cut. They are loosely defined as follows.

Upland - area of elevated and generally rocky terrain with high to moderate gradient drainage lines

Lowland - area of generally level terrain with low gradient drainage lines

WU UPLAND WATER COURSES

The majority of upland channels are relatively steep and small but include sections of low gradient sometimes with River Red Gums and or *Melaleuca* species.

WU1 Upland Waterholes

Basins within watercourses: hold still water after channels cease flowing on surface (or relatively still water in a few permanent spring fed streams)

WU1.1 Generally Wet Upland Waterholes (permanent & long-term)

There is considerable variation in sizes, landform and vegetation. Also includes smaller, obviously spring fed rockholes. Subcategories of permanent, semi-permanent, rarely dry and occasionally dry are used to describe individual wetlands in this category. Some waterholes are generally wet due to reliable springs, which may flow directly into the waterhole or flow in via the channel. Others rely on shading by the surrounding terrain for their longevity.

WU1.1.1 Permanent Upland Waterholes

WU1111 Permanent Upland Waterholes

Where exposed bedrock predominates on the sides and banks, the term rockhole is often used.

WU1.1.2 Non-Permanent but Long-term Upland Waterholes

Some of these are inundated by semi-permanent to long-lasting but temporary springs, for instance some in the Anmatjirra and Yundurbulu ranges. There is often insufficient information to classify non-permanent springs as either generally wet or long-lasting but generally dry.

WU1121 Non-Permanent but Long-term Upland Waterholes

These are generally wet but may occasionally dry out. Includes a wide range of sizes, substrates and fringing vegetation. Where exposed bedrock predominates on the sides and banks, the term rockhole is often used.

WU1.2 Temporary (Generally Dry) Upland Waterholes

WU1201 Temporary Upland Waterholes

There is considerable variation in sizes, landform and vegetation. Where exposed bedrock predominates on the sides and banks, the term rockhole is often used.

WU2 Upland Channels

Surface water generally running if present (i.e. doesn't include basins in channels).

WU2.1 Long Running Upland Channels

WU2101 Permanent Spring-fed Upland Streams

Typically these only run for a few metres to a few hundred metres before reaching loose, permeable substrates such that the water all sinks in and surface flow ceases.

WU2102 Non-Permanent but Long-term Spring-fed Upland Streams

These are streams produced by non-permanent Springs. Often there is insufficient information to determine longevity, and so those that are generally wet but occasionally 'fail' are not separated from temporary spring fed streams, such as from long-lasting but temporary running springs.

WU2.2 Generally Dry (Temporary) Upland Channels

WU2201 Generally Dry (Temporary) Upland Channels

This type could be separated according to substrate (bedrock, loose rock, sandy) and vegetation (e.g. wooded, shrubby) but generally brief inundation counts against doing so.

WL LOWLAND WATERCOURSES

The majority of lowland channels are relatively major watercourses but minor watercourses emanating from ranges also occur.

WL1 Lowland Waterholes (includes all basins in lowland channels, including rockholes)

WL1.1 Generally Wet Lowland Waterholes

Includes large rockholes in the Davenport, Murchison and Dulcie Ranges in gorges within, rather than through, the ranges. These could potentially be classified as uplands, but the gradient is generally low and the waterholes and watercourses are relatively large.

WL1.1.1 Permanent Large Riverine Waterholes

Permanent waters are separated for their importance for fishes and a few plants. The following types are separated on the basis of landform but other divisions such as on size may also be useful.

WL1111 Permanent Lowland Waterholes at the Base of Ranges

Occurring at the base of hill/mountain ranges where drainage channels emerge from gullies, including plunge pools below waterfalls and cascades. The waterholes are typically confined by bedrock and the term rockhole is often included in the wetland name.

WL1112 Permanent Lowland Waterholes in Gaps and Gorges

Confined and shaded by hill/mountain ranges on either side, where a major channel cuts a gap or gorge in the range. The waterholes are confined by bedrock but may be flanked by river sediments. Where exposed bedrock predominates on the sides and banks, the term rockhole is often included in the wetland name.

WL1113 Other Permanent Lowland Waterholes

Includes waterholes confined by hill/mountain ranges or smaller rock outcrops, and presumably by bedrock below the waterhole and also some more distant from ranges which are spring fed.

WL1.1.2 Generally Wet Large Riverine Waterholes

WL1121 Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges

Occurring at the base of hill/mountain ranges where drainage channels emerge from gullies, including plunge pools below waterfalls and cascades. The waterholes are typically confined by bedrock and the term rockhole is often included in the wetland name.

WL1122 Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges

Confined and shaded by hill/mountain ranges on either side, where a major channel cuts a gap or gorge in the range. The waterholes are confined by bedrock but may be flanked by river sediments. Where exposed bedrock predominates on the sides and banks, the term rockhole is often included in the wetland name.

WL1123 Other Generally Wet Non-permanent Lowland Waterholes

Confined and shaded by hill/mountain ranges on either side, where a major channel cuts a gap or gorge in the range. The waterholes are confined by bedrock but may be flanked by river sediments. Where exposed bedrock predominates on the sides and banks, the term rockhole is often included in the wetland name.

WL1124 Large Turbid Near-Seasonal Lowland Waterholes

Waterholes in large channels, confined by clay soils. Some are semi-permanent but most dry out more often. These occur in the north-east of the arid NT where rainfall from the summer monsoon is relatively reliable.

WL1.2 Temporary (Generally Dry) Riverine Waterholes

WL1202 Temporary (Generally Dry) Lowland Waterholes

Includes a broad range of sizes and topographies of waterholes. Various subdivisions could be made based on the basis of size, depth, substrate and fringing vegetation. Further analysis of survey data from the inventory could assist with this in the future.

WL2 Temporary (Generally Dry) Lowland Channels

Those parts of watercourses that are not waterholes. Water is generally running if present, but rarely runs on the surface for longer than days or weeks. Various subdivisions could be made based on the basis of size, depth, substrate and fringing vegetation. Further analysis of survey data from the inventory could assist with this in the future.

WL2001 Major Wooded Watercourses

Large temporary watercourse lined and sometimes studded with Eucalypt trees.

WL2002 Minor Lowland Wooded Watercourses

Small watercourse lined and sometimes studded with Eucalypt trees.

WL2003 Melaleuca Dominated Lowland Watercourses

Watercourse lined and often with islands of Teatree (*Melaleuca spp.*). Minor and intermediate size channels.

WL2004 Acacia Dominated Lowland Watercourses

Watercourse lined with *Acacia spp.*. Minor and intermediate size channels.

WL2005 Unwooded Lowland Watercourses

Watercourse in lowlands without fringing trees or shrubs. Minor and intermediate size channels.

WL2006 Braided Channels

Areas of multiple channels flowing in the same direction, resulting from a major channel upstream. Rare in the arid NT.

WL2007 Highly Saline Channels

Relatively minor channels with thick salt crust when dry.

SPRINGS, SEEPAGES & ASSOCIATED WETLANDS

Springs and seepages are included separately in the classification due to their general importance as long-term water sources in arid environments. Some types of groundwater discharge that do not produce any surface flow are not included here: those that emerge directly into permanent and other generally wet waterholes; those that discharge into soils in swamps and salt lakes. There is a primary subdivision of types of springs and seepages into uplands and lowlands. Other subdivisions are made on volume of flow, longevity, topographic position and salinity.

For some broad types only non-saline (< 1000 ppm TDS) types are listed. Saline types may be added if shown to occur in the arid NT. Some types are distinguished as saline or semi/saline. In those types the emerging ground water is semi-saline to saline and of sufficient salinity that substantial parts of the associated wetland are saline or at least favour salt tolerant plant species.

SU UPLAND SPRINGS AND SEEPAGES

SU1 Running Upland Springs

These produce sufficient volume to flow in small creeks. There is considerable overlap of these types with: WU2.1 'Long Running Upland Channels'.

SU1.1 Generally Wet Running Upland Springs

SU1101 Permanent Running Upland Freshwater Springs

Includes associated small permanent pools and swamps with ferns or sedges. Those that are known are very low salinity.

SU1102 Generally Wet Running Upland Springs (non-permanent)

Includes a range in water chemistry. Most examples are in or adjacent to creeks. Includes permanent and other long-term springs.

SU1.2 Temporary (Generally Dry) Running Upland Freshwater Springs

SU1.2.1 Freshwater: Intermittently Running Upland Freshwater Springs

SU1211 Temporarily Running (generally dry) Freshwater Upland Springs

Includes a range in water chemistry. Most examples are in or adjacent to creeks. Includes permanent and other long-term springs.

SU2 Minor Springs and Seepages in Uplands

Includes slight trickle but insufficient to run down minor channels. There may be associated water pools.

SU2.1 Minor Springs and Seepages in Sheltered Gorges

SU2.1.1 Freshwater Minor Springs and Seepages in Sheltered Gorges

SU2111 Permanent Sheltered Freshwater Minor Springs and Seepages

Permanent springs/seepages in sheltered gorges; including on rock walls and typically with relictual ferns.

SU2112 Non-permanent Sheltered Freshwater Minor Springs and Seepages

Includes generally wet and temporary springs/seepages in sheltered gorges. These are poorly known and further separation of longevity categories as wetland types is not justified.

SU2.2 Minor Springs and Seepages in Exposed Upland Terrain

SU2201 Generally Wet Minor Springs and Seepages in Exposed Upland Terrain

Includes those in drainage lines as well as others. Includes very minor soakages in sandy creeks and those that form small pools in rockier areas. Few such wetlands are documented sufficiently to distinguish permanent from other generally wet seepages. A considerable range in salinities is likely.

SU2202 Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry)

Includes those in drainage lines and on hill sides, the latter typically being on the mid-lower slope above a drainage line. A considerable range in salinities is likely.

SL LOWLAND SPRINGS AND SEEPAGES

SL1 Running Springs in Lowland Watercourses

Relative high flow.

SL1.1 Running Springs in Lowland Drainage Lines

SL1.1.1 Running Freshwater Springs in Lowland Drainage Lines

SL1111 Generally Running Freshwater Springs in Lowland Drainage Lines

Very little data on occurrence.

SL1112 Temporary (generally dry) Running Freshwater Springs in Lowland Drainage Lines

Very little data on occurrence.

SL1.1.2 Running Saline and Semi-saline Springs in Lowland Drainage Lines

SL1121 Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines

At least one known occurrence.

SL1122 Temporary (generally dry) Running Saline/Semi-saline Springs in Lowland Drainage Lines

Very little data on occurrence.

SL2 Minor Springs and Seepages in Lowlands

Includes slight trickle but insufficient to run in minor channels.

SL2.1 Minor Springs and Seepages in Lowland Drainage Lines

SL2.1.1 Freshwater Minor Springs and Seepages in Lowland Drainage Lines

SL2111 Freshwater Minor Springs and Seepages in Lowland Drainage Lines

A range of reliability/longevity is included. One such spring in the Finke River has the regionally rare Bladey Grass (*Imperata cylindrica*). Various springs in Palm Creek are arguably in this category but might alternatively be considered upland or intermediate.

SL2.1.2 Saline and Semi-saline Minor Springs and Seepages in Lowland Drainage Lines

SL2121 Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines

A range of reliability/longevity is included. One such spring, in a tributary of the Finke River in the Glen Helen area, has formed a mound of calcified organic matter on the banks of a minor lowland creek. The creek is close to low hills and is arguably upland or intermediate.

SL2.2 Lowland Springs and Seepages not in Drainage Lines

SL2.2.1 Freshwater Lowland Springs not in Drainage Lines

SL2211 Freshwater Lowland Springs and Seepages not in Drainage Lines

A range of reliability/longevity is included. Flow is generally minor. Includes isolated soaks in sand country and at the base of granitic ranges, some of which only marginally qualify as wetlands. No subdivision is made on longevity due to very little data on occurrence and nature.

SL2.2.2 Saline and Semi-saline Lowland Minor Springs and Seepages not in Drainage Lines

SL2221 Long-term Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline

At least one occurrence

SL2222 Temporary Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline (generally dry)

Widespread after periods of above average annual rainfall in landscapes with salt lakes.

SL2223 Mound Springs - Saline/Semi-saline

One known active mound spring is known in the arid NT, that is not associated with a drainage line. The aquifer is not part of the Great Artesian Basin. Several other mounds in the same valley are presumed to be extinct springs and another near by is active but has only a slight mound and is associated with a drainage line.

SL2224 Other Saline/Semi-saline Lowland Springs

Not in or associated with drainage lines, mounds or salt lakes.

SUBTERRANEAN (UNDERGROUND) WETLANDS

U0001 Underground Waterfilled Spaces in Rock with Macroscopic Invertebrates

ARTIFICIAL WETLANDS

A1 Stored rainfall runoff

A1001 Dams Across Watercourses

A1002 Excavated Dams/Tanks in Swamps and Pans

A1003 Other excavations: quarries, borrow pits, mine pits

A2 Bore Water

A2001 Excavated Dams Filled from Bores

Often store surface runoff but tend to be long-lasting or semi-permanent due to bore water and can be important in the persistence of introduced and natural fish species.

A2002 Built-up Earth Tanks Filled from Bores

Commonly called Turkeys Nests.

A2003 Minor Overflow from Bores

Typically intermittent and results in very small areas of swamp vegetation.

A2004 Open Metal/Concrete Tanks filled from Bores

Typically only a few metre diameter but often with aquatic plants and occasionally used by waterbirds.

A2005 Rogue Bores

Bores into the Great Artesian Basin, with vast uncontrolled flows; all have or will be rehabilitated to stop or drastically reduce flows.

A3 Sewage Water

A3001 Sewage Ponds

Typically support some wetland plants and lots of waterbirds. Large sewage ponds are restricted to a few major settlements.

A3002 Swamps Created/Modified By Treated Sewage

Typically support some wetland plants and waterbirds.

A4 Mining Effluent

A4001 Mining Tailings Ponds

Typically biologically dead due to heavy metals and cyanide. Use by waterbirds often results in deaths.

Comparisons with Other Classifications

The use of landform as the main upper level attribute in the arid NT wetland classification, follows Semeniuk (1987 as cited in Finlayson 1999) and was chosen to facilitate inventory. However, the inclusion of springs and artificial wetlands at the upper level of the classification weakens the hierarchical structure since both major landform and an aspect of water source are used. The benefits in terms of separating strong differences in ecological character, outweigh possible advantages of a stricter hierarchy. In this regard the arid NT wetland classification is more similar to the Ramsar classification, which is not hierarchically structured and is essentially a list of wetland types. Other attributes such as salinity, permanence/longevity and vegetation were considered for inclusion or combination into the upper level. However, these were rejected because of variability in state through time (salinity and vegetation) and because of difficulty in obtaining information about the attributes (salinity and permanence/longevity). Unlike the Ramsar classification, there is some hierarchical structure in our classification, which facilitates reporting numbers and extent of wetlands in each wetland type or broad type. The classification developed for the inventory of wetlands in Queensland (Blackman *et al.* 1992) is more strictly hierarchical. It is not based on delineating wetland types, being open ended. A system based on wetland types was considered more appropriate for a reconnaissance level inventory of relatively poorly known or documented wetlands, such as those in the arid NT. Our classification supports the essential task of describing and communicating important wetland types for conserving biodiversity.

Some of the key attributes used in the classification are also consistent with three broad divisions recognised by Williams (1985), who classified temporary waters as: predictably filled versus unpredictably filled; saline versus fresh; and discrete basins versus basins associated with rivers. The arid NT classification is also consistent with the broad classification of South Australian inland wetlands into swamps, lakes, rivers and springs, with further subdivision according to salinity and water regime (Lloyd & Balla 1986 as cited in Pressey & Adam 1995).

Our classification is much more detailed than the equivalent Ramsar types (15 compared to 71) and includes some types for which there is no obvious Ramsar equivalent. Part of the reason for the much larger number of types is the recognition of variations in landform and hydrology within broader types

and the inclusion of some types which always only occupy small areas. These have been often given only brief treatment or are virtually ignored in many classifications, many of which are more focused on the importance of wetlands for waterbirds than other biota (Paijmans *et al.* 1985; Barson and Williams 1991). The increased attention given to small wetlands is in recognition of the importance of some small wetland types for biodiversity conservation and also the relative importance of small wetlands in predominantly arid surrounds. Such small wetlands in temperate or humid climates are often less distinct from the general landscape.

Some aspects of our classification will probably be revised in any future inventory work. The division of channels and springs into upland and lowland can be difficult to apply to individual wetlands, and some refinement of definitions or types may be helpful. Also, the division of permanent and semi-permanent waterholes into those in gorges or at the base of ranges may not be easy to apply. The distinction is intended to reflect the lower evaporation rates in gorges. A broader category reflecting proximity to outcropping rock could be easier to apply.

An important disadvantage of the flexible approach taken to the classification structure (hierarchy) is that any changes to the middle levels of the hierarchy will require renumbering of the alphanumeric codes for wetland types. However, such changes can be managed relatively easily with modern databases such that the correspondence of old and new codes can be recorded in link tables (lookup tables). The codes for wetland types are relatively cryptic and it is not anticipated that they will ever be used in presenting information without the verbal description of each type.

Status of the Classification

The classification has not yet been thoroughly tested against our survey data or the available mapping of wetlands. When this is done it is likely that some further refinements will be necessary at the lower subdivision levels. The 'testing' process could involve some numerical analysis of our survey data.

Ramsar Wetland Types in the Arid NT

The Ramsar list of wetland types is presented below, annotated with their occurrence in the arid NT. Those represented in the arid NT are in bold type and those that are absent are in italics. Comments in curly brackets '{ }' are made regarding the nature and extent of occurrence in arid NT.

Inland Wetlands

- L* *Permanent inland deltas.*
- M** **Permanent rivers/streams/creeks; includes waterfalls.** {restricted to a few small spring fed streams, mostly in hills}
- N** **Seasonal/intermittent/irregular rivers/streams/creeks.** {all episodic/intermittent; widespread with many variations of land form, vegetation and water regime; includes major rivers with River Red Gum (*Eucalyptus Camaldulensis*) woodland overstorey in and/or adjacent to the main channel}
- O* *Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.*
- P** **Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.** {all episodic/intermittent; uncommon}
- Q* *Permanent saline/brackish/alkaline lakes.*
- R** **Seasonal/intermittent saline/brackish/alkaline lakes and flats.** {all episodic/intermittent but may last more than 12 months; widespread but not throughout arid NT; including some of great size}
- Sp* *Permanent saline/brackish/alkaline marshes/pools.*
- Ss** **Seasonal/intermittent saline/brackish/alkaline marshes/pools.** {all episodic/intermittent; widespread but patchy distributions in arid NT; includes samphire (*Halosarcia spp.*) and some other chenopods}
- Tp** **Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.** {virtually all associated with mountain ranges; includes permanent waterholes in drainage lines, mostly confined by rock and with

some degree of shading; mostly fed by groundwater discharge; includes some small spring fed swamps in gullies}.

Ts **Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.** {all episodic/intermittent with a variety of perennial and non-perennial vegetation}

U *Non-forested peatlands; includes shrub or open bogs, swamps, fens.*

Va *Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.*

Vt *Tundra wetlands; includes tundra pools, temporary waters from snowmelt.*

W **Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.** {all episodic/intermittent with a variety of perennial and non-perennial vegetation; includes Bluebush (*Chenopodium auricomum*) swamps and Lignum (*Muehlenbeckia florulenta*) swamps, but also some dominated by Old Man Saltbush (*Atriplex nummularia*); this type could also be used for some swamps dominated by various species of low, semi-woody sub-shrub}

Xf **Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.** {all episodic/intermittent; typically dominated by Coolabah trees (*Eucalyptus coolabah* & *E. victrix*) but also sometimes River Red Gum (*E. camaldulensis*) and rarely Bastard Coolabah (*E. intertexta*); often occurs in linear strips adjacent to major rivers and fringing unwooded swamps and claypans but also as the dominant wetland type in some basin swamps}

Xp *Forested peatlands; peat swamp forests.*

Y **Freshwater springs; oases.** {varying levels of salinity, volume and reliability of flow; there are no Great Artesian Basin springs; the majority of reliable springs producing surface water flows are in or adjacent to ranges but not all; there are many intermittent springs adjacent to saline lakes and a few springs that have formed mounds; there are other areas of groundwater discharge, into permanent waterholes and into the hyporheic zone of rivers}

Zg *Geothermal wetlands.*

Zk(b) – Karst and other subterranean hydrological systems, inland {widespread even though limestone cave systems and surface features of karst are virtually unknown; bore holes in calcrete and limestone areas often yield both macroscopic and microscopic aquatic invertebrates}

Note : ‘floodplain’ is a broad term used to refer to one or more wetland types, which may include examples from the R, Ss, Ts, W, Xf, Xp, or other wetland types. Some examples of floodplain wetlands are seasonally inundated grassland (including natural wet meadows), shrublands, woodlands and forests. Floodplain wetlands are not listed as a specific wetland type herein.

Human-made wetlands

1 *Aquaculture (e.g. fish/shrimp) ponds*

2 **Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).** {various types are common: dams across watercourses and valleys, including natural swamp areas; built up earth tanks, into which water is pumped (turkeys nests); and excavated tanks in swamps and claypans}

3 *Irrigated land; includes irrigation channels and rice fields.*

4 *Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture).*

5 *Salt exploitation sites; salt pans, salinas, etc.*

6 **Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha).** {relatively few large dams exist}

7 **Excavations; gravel/brick/clay pits; borrow pits, mining pools.** {borrow pits are common along major roads and the Alice Springs to Tarcoola Railway}

8 **Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.** {there are large sewage ponds in Alice Springs which overflow into a natural swamp altering the water regime; smaller ones at some other communities}

9 *Canals and drainage channels, ditches.*

Zk(c) *Karst and other subterranean hydrological systems, human-made*

Arid NT Wetland Types and Equivalent Ramsar Types

The relationship between Ramsar types and Arid NT Wetland Types is given in table 11.

Table 11. Summary of Arid NT Wetland Types and Equivalent Ramsar Types

Arid NT Code	Arid NT Wetland Type	Ramsar Code
Basins		
B1111	Highly Saline Lakes (Salt Lakes)	R
B1121	Saline Lakes / Samphire Swamps	R, Ss
B1122	Saline Lakes / Non-Samphire Chenopod Swamps	R, Ss
B1211	Large Freshwater Lakes and Pans	P
B1221	Small Freshwater Lakes and Pans	Tp
B1222	Isolated Rock Holes	Tp
B2111	Samphire Saline Swamps	Ss
B2112	Non-Samphire Chenopod Saline Swamps	Ss
B2121	Saline Grassy Swamp	Ss
B2211	Wooded Swamps (Non-linear)	Xf
B2212	Wooded Swamps (Linear/Riverine)	Xf
B2221	Bluebush Swamps	W
B2222	Lignum Swamps	W
B2223	Other Shrubby Freshwater Swamps	W
B2231	Grassy Freshwater Swamps	Ts
B2232	Herbaceous Swamps (non-grassy)	Ts
Flats		
F0001	Bare Flood-prone Flat	Ts
F0002	Wooded Flood-prone Flat	Ts
F0003	Shrubby Flood-prone Flat	Ts
F0004	Grassy Flood-prone Flat	Ts
Watercourses		
WU1111	Permanent Upland Waterholes	Tp
WU1121	Non-Permanent but Long-term Upland Waterholes	Ts
WU1201	Temporary Upland Waterholes	Ts
WU2101	Permanent Spring-fed Upland Streams	M
WU2102	Non-Permanent but Long-term Spring-fed Upland Streams	N
WU2201	Generally Dry (Temporary) Upland Channels	N
WL1111	Permanent Lowland Waterholes at the Base of Ranges	Tp
WL1112	Permanent Lowland Waterholes in Gaps and Gorges	Tp
WL1113	Other Permanent Lowland Waterholes	Tp
WL1121	Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges	Ts, N
WL1122	Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges	Ts, N
WL1123	Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges	Ts, N
WL1124	Large Turbid Near-Seasonal Lowland Waterholes	Ts, N
WL1202	Temporary (Generally Dry) Lowland Waterholes	Ts, N
WL2001	Major Wooded Watercourses	N
WL2002	Minor Lowland Wooded Watercourses	N
WL2003	Melaleuca Dominated Lowland Watercourses	N
WL2004	Acacia Dominated Lowland Watercourses	N
WL2005	Unwooded Lowland Watercourses	N
WL2006	Braided Channels	N
WL2007	Highly Saline Channels	N, Ss
Springs		
SU1101	Permanent Running Upland Freshwater Springs	M, Y
SU1102	Generally Wet Running Upland Springs (non-permanent)	Y, N

SU1211	Temporarily Running (generally dry) Freshwater Upland Springs	Y,N
SU2111	Permanent Sheltered Freshwater Minor Springs and Seepages	Y
SU2112	Non-permanent Sheltered Freshwater Minor Springs and Seepages	Y
SU2201	Generally Wet Minor Springs and Seepages in Exposed Upland Terrain	Y
SU2202	Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry)	Y
SL1111	Generally Running Freshwater Springs in Lowland Drainage Lines	Y
SL1112	Temporary (generally dry) Running Freshwater Springs in Lowland Drainage Lines	Y
SL1121	Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines	~
SL1122	Temporary (generally dry) Running Saline/Semi-saline Springs in Lowland Drainage Lines	~
SL2111	Freshwater Minor Springs and Seepages in Lowland Drainage Lines	Y
SL2121	Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines	~
SL2211	Freshwater Lowland Springs and Seepages not in Drainage Lines	Y
SL2221	Long-term Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline	~
SL2222	Temporary Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline (generally dry)	~
SL2223	Mound Springs - Saline/Semi-saline	~
SL2224	Other Saline/Semi-saline Lowland Springs	~
Subterranean (underground)		
U0001	Underground Water filled Spaces in Rock with Macroscopic Invertebrates	Zk(b)
Artificial		
A1001	Dams Across Watercourses	2,6
A1002	Excavated Dams/Tanks in Swamps and Pans	2
A1003	Other excavations: quarries, borrow pits, mine pits	7
A2001	Excavated Dams Filled from Bores	2
A2002	Built-up Earth Tanks Filled from Bores	2
A2003	Minor Overflow from Bores	~
A2004	Open Metal/Concrete Tanks filled from Bores	2
A2005	Rogue Bores	~/Ts/O/P
A3001	Sewage Ponds	8
A3002	Swamps Created/Modified By Treated Sewage	8/Ts
A4001	Mining Tailings Ponds	8



6. Descriptions of the Wetland Types

Scope

The following descriptions of arid NT wetland types include the landform, longevity, salinity and dominant vegetation. Examples are given of important wetland types. Some wetland types are not individually described but are discussed along with other related types within the same 'broad wetland type'. A photographic summary of wetland types in the arid NT is given in appendix 1. Additional information on characteristic plants is found in chapter 9. These descriptions are designed to stand alone, with minimal cross referencing to other sections of the report. Accordingly, there is some repetition of information presented elsewhere. The descriptions provide a basis for preparing wetland educational material, but in the present form are too technical and long for some uses.

It is important to stress that there is considerable variation within most types and some types may inter-grade with others. Also, many wetlands of one type will have elements of other types within them.

6.1 Saline Wetlands: Salt Lakes and Swamps

Saline wetlands have been loosely defined here as those with salinity greater than 3000 ppm total dissolved solids and semi-saline as those with between 1000 and 3000 ppm. However, salinity levels below 1000 ppm may also favour salt tolerant plants and water salinity often varies with the volume of water present. Consequently, saline swamps may be better identified on the basis of salt tolerant vegetation species than on somewhat arbitrary and preliminary threshold values of salinity. Future analysis of the soil and vegetation data from the wetlands survey may allow a more precise definition of semi-saline and saline to be incorporated into the definitions of saline wetland types.

Bare Salt Lakes

Predominantly bare saline lakes are classified as:

B1111 Highly Saline Lakes (Salt Lakes).

There are a wide variety of salt lakes; some very shallow, some several metres deep; some small and some huge. The vast salt lakes only fill infrequently, from about 4 to 10 times a century. When inundated they provide by far the largest area of wetlands and can support thousands of waterbirds. The patchy distribution of rainfall, even in the wettest years, means that the larger lakes are rarely full at the same time.

Some of the deeper and longer lasting salt lakes are several metres deep when full, such as Lake Lewis, and various lakes in the Karinga system including Lake Pulcura. At the other extreme are those that are typically very shallow (< 50 cm) such as Lake Bennett and Lake Amadeus. Lake Mackay, the fourth largest lake in Australia, is thought to be intermediate. Depth (maximum or typical) has not been included as a classification attribute since it is not known for many lakes.

Saline lakes are created by permanent or long-term groundwater discharge directly below the lake bed, resulting in areas of permanently saturated hyper-saline soils (brine). A chain of saline lakes (playas), extends 500km from Lake Hopkins in Western Australia to the Finke River at Idracowra and includes

Lake Neale and Lake Amadeus. It also includes a group referred to here as the Karinga Creek Paleodrainage System which consists of more than 100 smaller playas between Curtin Springs and Idracowra. The hydrology and landform of the entire chain has been relatively well studied, as summarised by Jacobson (1996). The area is known as the 'Central Australian Groundwater Discharge Zone'. It includes a group of lakes near Curtin Springs Roadhouse that may be the most saline in Australia with brines between 350,000 and 400,000 ppm TDS (Jacobson 1996). Another chain of salt lakes extends from Lake Lewis to Lake Bennett. Information on the hydrology of these is provided by Wischusen (1998).

The salinity and chemical composition of saline wetlands vary. The surfaces are typically a white halite crust, but many other minerals are also precipitated out of groundwaters. Some, but not all form substantial and visually dramatic salt crusts when dry while others have relatively minimal crusting. The degree of crusting may vary across a single lake. Parts of the bed of Lake Amadeus are dominated by brown gypsum whilst others have a white crust (Jacobson 1996). Water from a soil pit in Lake Bennett had a conductivity of 156,000 μ S/cm (lower limit for hypersaline c. 44,000 μ S/cm) yet it is reported that this lake only forms a minimal crust. Some lakes have significant proportions of gypsum (calcium sulphate) as well as sodium chloride and other minerals. As there is no quick field test for gypsum the distinction can be hard to make, but the presence of gypsum crystals in unsaturated soils is a good indicator.

The majority of saline lakes are not filled from a major drainage channel. Lake Lewis is the main exception. Most saline lakes are filled from relatively local runoff and minor channels. Sheet flow across the landscape may also be significant in widespread and intense rain events. Some inflow comes from springs on the edges of lakes. Many salt lakes function as a window on the watertable, which may be elevated after large regional rainfall events, resulting in increased groundwater discharge and sometimes also surface water. Elevated watertables in surrounding drylands and swamps may be manifested as surface water in the lakes which are at lower elevations.

Most salt lakes are fringed by a distinctive suite of salt tolerant plants, many of which are succulent. Salt tolerant species can extend across parts of the lakebed to form a vegetated swamp. Species of *Halosarcia* typically dominate, forming a low shrubland known as samphire.

Some large salt lakes have adjacent freshwater pans perched above the saline watertable.

Vegetated Saline Basins

Vegetated saline basins are divided into those where inundation typically submerges vegetation (lakes), and those where the vegetation is emergent during full inundation (swamps). A further distinction is made in vegetated saline swamps and lakes, based on vegetation type, which may equate to level of salinity. The individual wetland types in vegetated saline basins are:

B1121 Saline Lakes / Samphire Swamps (vegetation can be fully submerged)

B1122 Saline Lakes / Non-Samphire Chenopod Swamps (vegetation can be fully submerged)

B2111 Samphire Saline Swamps (vegetation never fully submerged)

B2112 Non-Samphire Chenopod Saline Swamps (vegetation never fully submerged)

B2121 Saline Grassy Swamps (vegetation never fully submerged).

Saline basins that are predominantly vegetated with salt tolerant plants are broadly grouped as saline swamps but may be classified primarily as saline lakes if the vegetation is fully submerged when the basin is filled with water. Typically they are less saline than the bare salt lakes and there is a range in salinity values reflected in the plant species present. With lower salinity, samphire may be replaced by other chenopods or grasses as the dominant plants.

Most salt tolerant vegetation is less than 1m high. An exception is Oldman Saltbush (*Atriplex nummularia*) which occurs in some semi-saline areas but only occasionally in swamps.

Samphire species (*Halosarcia spp.*) are considered to be the most salt tolerant with others being less so, such as some *Atriplex spp.*, *Lawrencia spp.*, some *Chenopodium spp.*, some *Dysphania spp.*, *Eragrostis dielsii*, *E. falcata*, *Triodia salina* and *Osteocarpum spp.*. There is little data from which to describe the

nature of Saline Grassy Swamps and this type may only occur as an element within multi-type wetlands or as patches within wetlands dominated by a single other type.

The vegetation of saline arid NT wetlands has much in common with coastal salt marshes. Indeed, the term salt marsh is sometimes applied to inland saline swamps including the fringes of salt lakes (Moore 1968, The Macquarie Dictionary 1981); however, it is usually used exclusively for coastal, intertidal areas, and therefore, it is not used here for inland areas. The vegetation of Australian salt marshes is summarised by Adam (1994) in the chapter on saltmarsh and mangroves, in *Australian vegetation* (Groves 1994), and includes a useful summary of the eco-physiology of saline wetland plants. A numerical analysis of salt marsh flora of Western Australia by Cresswell and Bridgewater (1998) also provides a useful comparison with arid NT saline swamps. Several of the species and genera listed as characteristic of coastal salt marsh in Adam (1994) and Cresswell and Bridgewater (1998) are also present in arid NT saline wetlands: *Juncus kraussii*, *Sporobolus virginicus*, *Halosarcia indica subsp. leiostachya* and *subsp. bidens*, *Hemichroa diandra*, *Lawrencia*, *Frankenia* and *Sclerostegia*.

Saline Channels

Additional saline wetlands that are often associated with saline basins are saline channels and saline springs. Springs are grouped separately in this classification. Highly saline channels occur on the margins of highly saline lakes but also at distances of kilometres from salt lakes, such as in the Sangsters Bore area of the Tanami Desert. They are recognised as a distinct wetland type:

WL2007 Highly Saline Channels.

Although this type is grouped with drainage line features in the classification (WL prefix), it is listed here because of the strong affinity with salt lakes.

6.2 Freshwater Basins: Claypans and Lakes

There is a great variety of freshwater basins. Basin is used here for water holding areas that are not part of a watercourse (although they may receive water from channels).

All basins with open surface water when inundated (little or only fringing emergent vegetation) are classed as open freshwater basins. This includes those substantially covered by vegetation which is submerged when the wetland is fully inundated. Two wetland types are recognised, separated on size, for compatibility with the Ramsar classification (> 8 ha or < 8 ha):

B1211 Large Freshwater Lakes and Pans; and

B1221 Small Freshwater Lakes and Pans.

The distinction between open freshwater basins (lakes) and those with emergent vegetation (swamps) is often not clear for a particular wetland due to many variations and intergrades. It is often difficult to estimate maximum potential water depth, so a wetland might be classified as a swamp because it has been observed with emergent vegetation but does in fact function as a lake during deeper inundations.

Wide variations occur in landform, vegetation and water regime, but a meaningful subdivision into finer wetland types has not yet been created. Numerical analysis of survey data may assist in that task. The main variations are described below.

Claypans, Gibber Pans and Herbaceous Pans

Open freshwater basins that are predominantly bare when dry are often called claypans but that term is used quite variably and so has not been included in the names of any wetland types. Shallow wetlands such as claypans are often called playas. All playa wetlands in the arid NT are assumed here to have a high clay content in either the surface or sub-soil and typically have hard clay or stony clay surfaces. Those that were sampled in our survey were variously salt crusted (see salt lakes above), stony, sandy or with clay of various cracking patterns on the surface. Surface clay varied from clay loam to light clay with occasional heavy clays (soil texture according to McDonald *et al.* 1990). Those that were sandy on top invariably had a clay layer at depth and sometimes had central areas of exposed clay. Non-saline pans

with a sandy surface generally had more vegetation cover than those with hard setting clay surfaces. Surface sand may indicate erosion of surrounding sandy landscapes.

Some claypans are fringed by Coolabah trees (*Eucalyptus coolabah subsp. arida* & *Eucalyptus victrix*) on one side or in a complete ring. Other claypans are fringed by Inland Teatree (*Melaleuca glomerata*), various other shrub species or have no woody vegetation. Some have patches of Swamp Canegrass (*Eragrostis australasica*) which can form dense thickets. Swamp Canegrass usually occurs in shallow areas and so is emergent. Where patches of Swamp Canegrass cover a significant portion of a pan the wetland can be classified as a swamp rather than an open freshwater basin.

Claypans occur in various landscapes including adjacent to mountain ranges, adjacent to rivers, in sanddunes and sandplains, in gibber plains and with rare examples in the black soil plains of the Mitchell Grass Downs bioregion (for example Bell Waterhole). Claypans in sanddune swales are typically small, but some claypans are vast, measuring kilometres long and wide.

Some pans are formed by slackwater deposits of fine sediments from extreme river flows and may occur in areas where there are no longer any active river channels. Erosion by wind (deflation) is an important force in maintaining and developing playas, with the bare surfaces allowing acceleration of winds across them; in both claypans and salt lakes. In some situations, fringing sand banks or dunes are deposits of material scoured by wind from the playa surface. Wind erosion may also cut through permeable surface soils to expose less permeable surfaces and thus form water holding pans.

There is a large range in the inundation regimes of claypans and other open freshwater basins. Waters may last several months to longer than a year (rarely). Water may come from adjacent hills, minor creeks and possibly also over-bank flow from large rivers. Some pans only receive water from direct rainfall and very localised runoff. In low rainfall areas in the south, these may be very rarely inundated. In the north of the arid NT the higher, more seasonal and slightly more reliable rainfall means that these isolated pans may hold water relatively frequently.

Some parts of the Simpson Desert have stony surfaces of closely packed gibber stones on plains and sometimes on low undulating hills, which produce substantially much more runoff than sanddunes. The distribution of the gibber is summarised by Purdie (1984) who notes that they are extremely impermeable to water. Gibber surfaced playas are distinguishable from gibber plains in general by being a depression with a surface lower than the surrounding landscape. They are typically very shallow, whereas some pans exceed 1 to 2 metres in depth.

Aggregations of claypans and swamps may be important waterbird habitats, with examples in the Finke bioregion (for example Palmer River area), Simpson Strzelecki Dunefields and the Great Sandy Desert bioregions.

Interdune Lakes

The deepest freshwater lakes occur in areas with large sanddunes and in some the water is apparently confined by ancient, relatively impervious land surfaces, of rock rather than clay. The main example is a series of very large inter-dune lakes in the Simpson Desert, which fill from Snake Creek. These are part of the greater floodout system of the Finke River and some have been measured at 9 to 10 metres deep with inundation lasting over two and a half years in places. Another large interdune lake was surveyed in the Great Sandy Desert Bioregion to the east of Lake Mackay. It was over 2km long and had an estimated maximum depth of 1.5 m, but the frequency of inundation is likely to be much less than the lakes at Snake Creek, as there is no coordinated drainage in the area.

The large freshwater lake fed by Salt Creek is partially confined by sand dunes, and inundation in 2000 lasted over two years.

6.3 Isolated Rock Holes

Isolated rockholes are water holding depressions in outcropping rock and are not part of a watercourse (channel). A single wetland type encompasses the variation in landform, rock type, size and shape:

B1222 Isolated Rock Holes.

It includes elevated rockholes in hills and ranges and low outcrops that are hardly elevated above the surrounding plain. They are filled totally from local rain runoff, and water can remain for several months, supporting a distinctive aquatic fauna. Even shallow rockholes such as on Uluru (Ayers Rock) can have a surprisingly high number of aquatic species, including shield shrimps (*Triops australis*) and the amphibious fern *Isoetes muelleri* (with grass like fronds).

The locations of isolated rock holes are well known to traditional Aborigines for whom they were an important water source. Some rock holes are traditionally maintained by cleaning out wind blown sediments and covering them with rocks or bushes to reduce evaporation and consumption by animals.

One particular type of isolated rockhole, called gnamma holes, occurs in hard and typically granitic rocks. They typically have round openings and are in the order of 1 metre in diameter and similar depth. According to Bayly (1999) they are formed by chemical weathering of initially smaller depressions. The word 'gnamma' is based on Western Desert Aboriginal languages for rockhole but the term is now consistently used for circular depressions in slabs and domes (Bayly 1999). The Macquarie Dictionary (1981) gives 'namma' as an alternative spelling and 'melon-hole' as a synonym. One of the authors of this report observed holes in the Murchison area of West Australia that were conical, being wider at the base than at the neck. He was told by pastoralists that these gnamma holes were significantly enlarged by Aborigines, using fire, water quenching and hammering. Gnamma holes observed in the arid NT are typically more cylindrical. Bayly (1999) notes that there are various reports of Aborigines protecting and prolonging water storage in gnammas by covering them with branches or flat rocks and cites observations by Tindale and Lindsay (1963) of channels carved in surrounding rock to divert water into gnammas.

Relatively large, but typically shallower rock basins occur on the plateau on top of the George Gill Range (north western end). They are roughly circular depressions in the bed rock which predominates the land surface, and are typically 20 – 30 m in diameter and 30 – 50 cm deep, with a silt bottom, and hold water for one to two months (D.Schunke, pers. comm.). In some ways they are similar to claypans, but as the water is confined by rock, they are included under isolated rockholes. The single arid NT record of a small sedge - *Eleocharis pusilla* - is known from this wetland type.

Glen Maggie Springs (Mutujulu Waterhole) at the base of Uluru (Ayers Rock) is also included as an isolated rockhole, even though it is at the base of Uluru with soil on some sides. It is a good example of the difficulty in assigning a wetland type for some wetlands. The waterhole is not in a well defined watercourse so it cannot be included under riverine waterholes.

Our 'isolated rockhole' wetland type also includes small caves such as are listed in Toyne (1995) for the Western Desert.

6.4 Wooded Swamps (freshwater)

Eucalypt wooded swamps are a widespread wetland type which have a distinctive groundcover flora following inundation. They can provide important habitat for wetland birds, particularly those that need to roost. There is considerable variation in landform, overstorey vegetation (species and structure), understorey vegetation and hydrology, and it is possible that in the future some additional wetland types will be recognised. Currently only two types are recognised:

B2211 Wooded Swamps (Non-linear)

B2212 Wooded Swamps (Linear/Riverine).

Most wooded swamps are dominated by Coolabah trees: either *Eucalyptus coolabah subsp. arida* in the south or *Eucalyptus victrix* in the north, or intermediate forms (possibly hybrids). Some wetland areas are dominated by River Red Gums (*Eucalyptus camaldulensis*) but these are typically indistinct basins in floodouts or floodplains adjacent to continuing channels. Accordingly, some may be better classified as

wooded flood prone flats. *Corymbia flavescens* (similar to Ghost Gums and sometimes called cabbage gums) occur in a few floodout areas with relatively short lasting inundation. The Palm Valley Palm trees (*Livistona mariae subsp. mariae*) form a linear woodland in places such as the Glen of Palms on Palm Creek. This area could be classified as a wooded watercourse or wooded swamp (linear/riverine). The ecological character of the area is more influenced by groundwater springs than by in-channel flow and so it is treated as a wooded swamp.

Non-linear wooded swamps include those that are terminal basins of channels and side channels, depressions within the floodplains and floodouts of major rivers and other landforms. There is considerable variation in the density of the trees from relatively dense woodland to very sparse open woodland. Even where the total cover of trees is less than 30% an area is still classified as a wooded swamp, as long as the trees are somewhat regularly spaced across the wetland, such that they strongly influence its ecological character. If the wooded areas are very patchy or are restricted to a fringe on the basin edge, then some other wetland type will best describe the wetland. It is very common for wetlands of other types to have wooded swamp listed as a secondary type.

Important examples of non-linear wooded swamps include Lake Surprise (Yinapaka), Mudhut Swamp, Woodduck Swamp, the Elkedra floodout swamps, and the Frew Floodout Wooded Swamp.

An example of swamp with emergent Coolabah trees that is not classified as wooded swamp is Indemina Swamp. It consists of three connected basins, of which one has a very sparse Coolabah woodland. It could marginally qualify as a wooded swamp, but overall, the three basins are better classified as freshwater lakes that dry back to herbaceous swamp.

The term gilgai has a quite well defined usage in soil science but also a broader use in central Australia to refer to heavy clay swamps, some of which have Coolabah woodland.

Linear or riverine wooded swamps are those that occur adjacent to major rivers, often on benches that are below the level of the main floodplain but are above the main channel or separated from it by a levee bank. They would appear to function in some ways as swamps, filled with still or relatively slow moving water from over-bank flow from the main channel. However, they are also distinctly linear landforms, which presumably have linear flows of water along them at times when they become part of a broad flowing watercourse. This wetland type also includes some swamp areas in interim floodouts. They are linear in shape and typically carry a linear flow of water, into channels that reform on the downstream side of the swamp.

A major part of the Finke floodout is dominated by Coolabah (*Eucalyptus coolabah subsp. arida*) and Cooba (*Acacia salicina*) the latter being either a large shrub or a single trunked tree. In many parts, the density of trees is such that the term forest is more applicable than woodland. Accordingly it is distinguished here, from other parts of the Finke Floodout, by the name 'Finke Floodout Forest'. This area has a very distinctive character and in some ways is more of a flat than a basin. It could potentially be given its own wetland type. Because of presumed linear flow through the floodout, which reforms as two significant channels at the eastern and south-eastern edges, the Finke Floodout Forest is included in B2212 Wooded Swamps (Linear/Riverine). Other wetland types in or adjacent to the floodout forest are waterholes, minor channels with Lignum (*Muehlenbeckia florulenta*), and distinct basins between dunes with Coolabah trees of varying density (B2211 Wooded Swamps (Non-linear)), some with dense tall verbine (*Cullen cinereum*) following the recession of waters. There is anecdotal evidence that the Finke Floodout Forest has become considerably more densely vegetated in recent decades, following major river flows in 1974. This may be due to long term recovery from a previous fire. The Finke Floodout Forest may also be influenced by increases in siltation from higher in the catchment.

6.5 Bluebush Swamps

The most abundant wetland shrub is Northern Bluebush (*Chenopodium auricomum*) which can form moderately dense shrub cover of around one metre in height over large areas and dominate whole basins. It is often the structural dominant in swamps, sometimes with scattered Coolabahs (*Eucalyptus coolabah subsp. arida* or *Eucalyptus victrix*) and frequently with annual herbs and grasses as an understorey

following the recession of inundation waters. Although there is some variation in the vegetation structure and associated species in swamps dominated by Northern Bluebush, a single and relatively uniform wetland type is recognised:

B2221 Bluebush Swamps.

Another shrub species with a similar common name, Southern Bluebush (*Maireana astrotricha*), occurs in the NT but is not characteristic of swamps. Accordingly the prefix 'northern' is not used in referring to bluebush swamps.

Most bluebush swamps do not fill every year and inundation seldom lasts more than about six months.

Northern Bluebush (*Chenopodium auricomum*) also occurs as an occasional element in some other types of swamp. It is palatable to cattle and consequently provides important pasture. It is reputed to be prone to eradication at sites if grazing is too intense.

Bluebush swamps may provide important shelter and nesting sites for wetland birds but this is unconfirmed in the study area.

6.6 Lignum Swamps

Lignum (*Muehlenbeckia florulenta*) is a highly characteristic wetland shrub that is common in the arid NT but rarely dominates large areas. Even so, a distinct wetland type is recognised:

B2222 Lignum Swamps.

This is to accommodate those basins that are dominated by Lignum and because it is an important secondary type at many wetlands, including some Coolabah Swamps and open freshwater basins.

The largest expanse of Lignum swamp is probably that part of Stirling Swamp which is adjacent to the Hanson River; an area that has not been adequately surveyed. Lignum is more often found as a fringe element of some riverine waterholes and in parts of some wooded (Coolabah) swamps.

Areas of Lignum swamp may provide important shelter and nesting sites for wetland birds but this is unconfirmed in the study area.

Gibson and Cole (1988) report patches of Lignum occurring in the Simpson Desert swales of the sand dune system fringing the 'Plenty River Salt Lakes'. Some of these patches were apparently a relatively rare understorey associated with a more widespread Gidgea (*Acacia georginae*) overstorey.

6.7 Other Freshwater Shrubby Swamps

Occasionally swamps are dominated by Acacia species but typically only where inundation is rare and short lasting. Examples of Acacia dominated swamps occur in river floodouts to the north of the Davenport Ranges. Several of these have an emergent overstorey of scattered gum trees (*Corymbia flavescens*) and there is at least one area in which *Melaleuca viridiflora* is a co-dominant shrub.

One example is known of a floodout swamp dominated by Mulga (*Acacia aneura*).

Melaleuca glomerata is a frequent and characteristic element of the fringe of claypans, semi-saline swamps and rivers but is rarely extensive enough to be the dominant species across a basin.

Melaleuca uncinata dominates some swamps in the south-west of the arid NT.

In the south west of the NT Nitre Goosefoot (*Chenopodium nitrariaceum*) dominates some swamps in a similar fashion to Northern Bluebush (*Chenopodium auricomum*) which it somewhat resembles.

Various semi-woody sub-shrubs are common in swamps and may dominate areas including *Pluchea spp.*

All the above variations are included in a single wetland type called:

B223 Other Shrubby Freshwater Swamps

6.8 Grassy and Other Herbaceous Freshwater Swamps

There are various freshwater swamps that are dominated by herbaceous plants, with only scattered or no trees and shrubs. Two types are recognised; those that are dominated by grasses and those dominated by other herbs:

B2231 Grassy Swamps

B2232 Herbaceous Swamps (non-grassy)

Grass dominated swamps are relatively uncommon in the arid NT. The largest examples are on the Barkly Tableland, with perennial tussock grasses including Silky Browntop (*Eulalia aurea*), Silky Bluegrass (*Dichanthium sericeum*) and Mitchell Grass species (*Astrebla spp.*). A large grassy swamp occurs at the junction of Manners Creek and a tributary running north from the Toko Ranges, in which the dominant grass species are Silky Browntop and Shedda Grass (*Dichanthium annulatum*), which is introduced (a weed). Several examples of small swamps dominated by Swamp Wanderrie grass (*Eriachne benthamii*) occur adjacent to tributaries of the Finke River and are typically just a few hectares in size. One of these was surveyed while inundated and had apparently held water for over 7 months, without degeneration or death of the emergent grass tussocks.

Small and large sedges and forbs (dictyledonous herbs) occasionally occur as the dominant vegetation in areas of large swamps as well as forming groundcover below some shrubby and wooded swamps. There is some difficulty in determining whether to classify such areas as swamps or open freshwater basins. Many plant species germinate in shallow water or wet mud and do most of their growing after surface water has gone. Even so, it is useful to describe herbaceous swamps as a separate wetland type since this state may characterise the wetland for a substantial period and possibly longer than the duration of free surface water (i.e. for longer than it functions as a lake or pond).

The ecological character of some wetlands is more strongly influenced by waterlogged soil than by free surface water. Some are included in the category of herbaceous swamps. These include areas of long-term groundwater discharge as well as some basins in which inundation is typically shallow and short lasting, but with longer lasting water-logging of soils, due to generally elevated watertables in the surrounding landscape.

Nardoo species (*Marsilea spp.*) are aquatic or amphibious ferns that often form dense mats in some swamps and claypans. When water is present, cloverleaf shaped fronds float on the surface. In some cases Nardoo may be the dominant vegetation cover during and following inundation, but as these species are non-perennial, they will not be evident during prolonged dry times. Thus, some areas may vary from bare clay to dense lush Nardoo meadows.

Budda Pea (*Aeschynomene indica*) is a fast growing annual that is widespread in swamps and can form tall dense stands following inundation, typically between one and two metres high. It can temporarily dominate the character of a wetland but is short lived and is often encountered as standing dead sticks. Verbine (*Cullen cinereum* and *C. australasicum*) are other annuals that can form dense stands over a two metres high. All three species can also occur as mixtures with other herbs and shrubs. Although they may not have the same abundance after every inundation, they can have a strong influence on ecological character.

Some distinctive small wetlands occur on red earth plains dominated by Mulga (*Acacia aneura*) shrubland. There are two main forms: small claypans and heaving clay depressions or gilgais. Both forms may support dense cover of Nardoo (*Marsilea spp.*), as well as other characteristic wetland plants including Bluebush (*Chenopodium auricomum*).

It should be noted that the distinction between freshwater and saline swamps is not always clear-cut and some wetlands contain saline and relatively freshwater sections. Stirling Swamp is an example of this.

One example of a herbaceous swamp (about 30m wide) on top of a rock range is known from Watarrka National Park (George Gill Range). Some swamps are also known from some flat topped (table top) hills in the south of the arid NT (P.Latz pers. comm.). There are probably other examples too, but swamps located on the tops of ranges are rare in the arid NT.

6.9 Flood Prone Flats

Flood prone flats are a marginal and poorly defined group of wetland types, associated with floodplains and floodouts. It approximates the term 'land subject to inundation' with the implication that inundation is not sufficient to result in swamp vegetation. The distinction from basins is not easily made. The main difference is that flats do not hold water on the surface for long. When water is present it is generally flowing, even if slowly. Flood prone flats often form the general landscape of floodplains and floodouts, with basins within them forming swamps and lakes. Various subdivisions of flats are possible but current information only justifies a very basic breakdown:

- F0001 Bare flood-prone flat
- F0002 Wooded flood-prone flat
- F0003 Shrubby flood-prone flat
- F0004 Grassy flood-prone flat

Areas marked as swamp on 1:250,000 topographic maps may be flood prone flats under the arid NT wetlands classification. A fairly large area marked as Thring Swamp on the western side of the Davenport Ranges is a floodplain of Wycliffe Creek and not a swamp in our classification system. A brief inspection during our survey found a mixture of types of flood prone flats, including substantial areas of predominantly bare, hard set clay.

Several examples of wooded flood prone flats were encountered, such as the flood plain of Mt Benstead Creek in the East MacDonnell Ranges. It is densely wooded with River Red Gum trees from a flood event several decades ago.

6.10 Watercourses

Most watercourses in the arid NT are considered to be wetlands. Even though some only carry or hold water briefly, most of them have riparian vegetation that depends on the intermittent flows. A possible exception is some small steep watercourses in bedrock which only ever carry water during and immediately after rain, and due to the bedrock do not support wetland plants. However, small residual pools within such watercourses do count as wetlands.

In the classification of arid NT wetlands, watercourses are primarily divided on landform, into upland and lowland. They are also divided at an upper level in the classification, into waterholes and channels. Waterholes are effectively basins within the watercourse and hold still water after most of the watercourse has ceased flowing and has no surface water. The channels are the rest of the watercourse. Waterholes which are predominantly bounded by bedrock are broadly referred to as rockholes. They typically have less fringing or emergent vegetation. They are not recognised as a distinct wetland type due to the many variations in amount of exposed bedrock.

Another important attribute used to distinguish separate wetland types is the longevity of surface water. Drainage channels only hold water when flowing (as defined here) and most do so only temporarily, with the exception being a few spring fed reaches, typically of only a few hundred metres length. Four broad categories of longevity are used in distinguishing wetland types: permanent; non-permanent but long-term (generally wet); near-seasonal; and temporary (generally dry). Near-seasonal applies to large waterholes in the north of the arid NT, where river flows are strongly associated with summer monsoon rains although these are not reliable, varying greatly between years.

Most of the water in watercourse wetlands comes from higher in the catchment as in channel flow. Other sources include local runoff, sheet flow across flats, water flow below the surface of the channel (in the hyporheic zone), and ground water discharge into the hyporheic zone or directly into permanent pools. All the large rivers in the arid NT are temporary, only flowing after rain. Rivers can be dry for years at a time and large flows are infrequent but can occur very rapidly. Water may only flow for short periods of days and weeks, however, following widespread heavy rains, some rivers, notably the Finke, can flow along substantial parts for months or even one to two years. Even when there is no surface flow, water continues to move along many rivers under the surface, including water from groundwater discharge.

Long-term Upland Streams and Waterholes

There are a few upland streams and waterholes in the arid NT that are permanent or only dry up occasionally. Most are spring fed. Because of the importance of permanent waters for the survival of fish and some other species, two types of longevity are recognised, distinguishing those that have never been known to dry out (permanent) from others that are non-permanent but nevertheless flow for long periods. The running channels and associated waterholes are separated, as part of the hierarchical approach to classification. This separation also reflects real differences in vegetation and use by aquatic fauna. Also, some of the long-term upland waterholes are not dependent on long-term running streams. Instead, their longevity is due to some combination of shading from the surrounding terrain and ground water discharge directly into the waterhole or from an adjacent seepage spring.

WU1111 Permanent Upland Waterholes

WU1121 Non-Permanent but Long-term Upland Waterholes

WU2101 Permanent Spring-fed Upland Streams

WU2102 Non-Permanent but Long-term Spring-fed Upland Streams

There is a distinct flora and fauna associated with permanent freshwater pools and springs. For example, Tassel Sedge (*Carex fascicularis*) is only known in central Australia from a single spring-fed wetland in the Chewings Range, where it grows on the edges of small pools. Another aquatic plant which is restricted in central Australia to permanent upland pools, is Swamp Lily (*Ottelia ovalifolia*), which is only known from pools in the catchment of Palm Creek and Bagot Creek.

There are several long-term waterholes in the Palm Valley area of which at least two have not been known to go dry and are treated as permanent. They are typically shallow and confined by bedrock and owe their longevity to aquifer discharge. They are classed as upland due to the surrounding terrain and an evident but shallow gradient, even though they are only a few metres in elevation above the main channel of the Finke River through Finke Gorge.

Yarribilong Rockhole on Newhaven Station is an example of a long-term upland waterhole that is near the bottom of a hill but not on the surrounding plains. The creek feeding out of it is very minor, rocky and has a low but obvious gradient following the gentle lower slopes of the range. A similar example is John Hayes Rockhole; a non-permanent but long-term waterhole in the East MacDonnell Ranges. The creek below John Hayes Rockhole is quite substantial, with moderately large River Red Gums, and the rockhole is really intermediate between upland and lowland. In this case, it is treated as lowland.

There are numerous small long-term upland waterholes in the George Gill Range in Watarrka National Park. It is possible that some are semi-permanent or permanent.

There are some relatively small but presumably permanent or semi-permanent upland waterholes that allow fish (*Leiopotherapon unicolor*) to survive in several creeks and rivers and are listed in the review of fishes in the arid NT (chapter 10).

Other examples of long-term upland wetlands and associated biota are discussed under the section on springs as there is some overlap between them. The running channels and associated pools are not springs but wetlands created by springs. However, in general usage, the term spring is often used as inclusive of the associated wetlands. There is often insufficient information to classify non-permanent springs as either generally wet or long-lasting but generally dry. Some springs are known to run for months to years following periods of prolonged high rainfall, but may also be dry for many years.

Temporary Upland Waterholes

The great majority of upland waterholes are temporary. They typically dry out between rainfall events and are more often dry than wet. A single wetland type incorporates a range of longevity, substrate, depth and vegetation:

WU1201 Temporary Upland Waterholes.

Generally Dry (Temporary) Upland Channels

Upland watercourses are those descending from hills and mountains and typically have relatively steep gradients, narrow channels and tend to have rocky substrates but also include sandy creek beds. They typically only run for days to weeks following rain. They tend to have fewer and smaller fringing trees than lowland watercourses, and where there is a significant amount of woody vegetation it is often dominated by *Melaleuca* species. All these variations are combined in a single wetland type:

WU2201 Generally Dry (Temporary) Upland Channels.

Permanent Lowland Waterholes

Lowland waterholes are those in watercourses with predominantly low gradients. Some are in small lowland watercourses but the long-term waterholes are mostly in medium to large watercourses. Waterholes in large watercourses in gorges and relatively open valleys passing between ranges are all counted as lowland, even though they may be flanked by rocky uplands. Waterholes at the base of ranges, such as plunge-pools, may be hard to classify as either upland or lowland. The size of the channel, gradient, substrate and surrounding terrain should be considered when determining the most useful category.

Permanent waterholes are defined as those which are not known to dry out in recorded or oral history. The permanent waterholes in the MacDonnell Ranges bioregion are quite well identified. Permanent lowland waterholes also occur in the Toko Ranges, Dulcie Ranges, the Davenport Ranges and in the Murchison Ranges, but there is generally less information for distinguishing permanent from other long-term but non-permanent ones. There are also some long-term and possibly permanent rockholes at the base of isolated ranges in the Great Sandy Desert Bioregion. Most of the permanent waterholes are at least moderately deep and large, but some are quite shallow, owing their longevity to aquifer discharge.

Three distinct types of permanent lowland waterholes in watercourses are recognised, based on surrounding landform:

WL1111 Permanent Lowland Waterholes at the Base of Ranges

WL1112 Permanent Lowland Waterholes in Gaps & Gorges

WL1113 Other Permanent Lowland Waterholes

Permanent Lowland Waterholes at the Base of Ranges occur at the base of hill/mountain ranges where drainage channels emerge from gullies, including plunge pools below waterfalls and cascades. The waterholes are typically confined by bedrock. On average, these waterholes are smaller than other permanent lowland waterholes. There are two such waterholes in the Finke River system (Upper Serpentine Gorge and Puka). Some of the permanent pools in the Davenport Ranges and the Murchison Ranges probably fit in this category, although the ranges are generally low and dissected. Similarly, some waterholes in the Dulcie Ranges may fit in this category but may not be permanent.

Permanent Lowland Waterholes in Gaps & Gorges are confined and shaded by hill/mountain ranges on either side, where a major channel cuts a gap or gorge in the range. The waterholes are confined by bedrock but may be flanked by alluvial sediments. Ellery Creek Bighole and Glen Helen Gorge Waterhole are the only examples in the Finke River system. There are long-term waterholes of this type in the Dulcie Ranges but more information is required to confirm which, if any, are permanent. There are several examples in the Davenport Ranges and probably in the Murchison Ranges, including: Old Policemans Waterhole, Kangaroo Rockhole and others in the Frew River system, and probably some in the upper Whistleduck Creek system. There are two permanent waterholes in the Elkedra River (R.Driver pers. comm.) that are presumed to best fit this wetland type.

Other Permanent Lowland Waterholes includes waterholes confined by hill/mountain ranges or smaller rock outcrops, and presumably by bedrock below the waterhole. This wetland type also includes some waterholes that are more distant from ranges and which are spring fed. Those in the Finke River system are: 2 Mile Waterhole (upstream of Glen Helen Gorge); Boggy Hole, Running Waters and Illara Waterhole. There are some near-permanent waterholes located away from the ranges in the Elkedra

River, but have been known to dry out at least once. Nora Waterhole in the Toko Ranges is believed to be permanent and best fit this wetland type. It is adjacent to low rocky ranges with a low cliff on one side but is not in a gorge or gap. It is likely that there are examples in the Davenport and Murchison Ranges.

Long-term but Non-permanent Lowland Waterholes

Long-term waterholes are any that are non-permanent but more often hold surface water than not. The term 'generally wet' is used here interchangeably with 'long-term' in describing the persistence of waterholes. Several categories of longevity can be used to describe individual waterholes but are not used to define extra wetland types:

Semi-Permanent - only dries out in the most severe droughts – in the order of once in 50 years or less frequently;

Rarely Dry - usually inundated but dries more frequently than semi-permanent - in the order of once in 10 to 40 years;

Occasionally Dry - usually inundated but dries out several times a decade - more frequently than once in 10 years.

As for permanent waterholes, separate wetland types are defined on the basis of landform.

WL1121 Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges

WL1122 Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges

WL1123 Other Generally Wet Non-permanent Waterholes

WL1124 Large Turbid Near-Seasonal Lowland Waterholes

WL1202 Temporary (Generally Dry) Lowland Waterholes

Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges includes Redbank Gorge Waterhole in the Finke River system. It is semi-permanent, having only been known to 'dry' once in recorded history, when it was filled with sand, thus displacing surface water. John Hayes Rockhole in the East MacDonnell Ranges is known to dry up more regularly, in droughts. It is treated as lowland and as discussed for upland waterholes, is a good example of a watercourse that is somewhat intermediate between hills (uplands) and plains (lowlands). Muranji Rockhole in the Cleland Hills is sometimes regarded as permanent but was encountered dry in May 1996 (Wischusen 1998) and should be regarded as 'rarely dry' with minimal or no groundwater input. It is a deep waterhole completely bounded by bedrock. There are several waterholes at the base of the George Gill Range which are often assumed to be permanent but are probably not. Brian Bowman was manager of the pastoral lease that included the Watarrka area for several decades from about the 1930s. He stated that in droughts there was no water that was accessible to cattle, including Reedy Rockhole which dried back to a seepage (P.Latz pers. comm.).

Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges includes Simpsons Gap and Bond Gap waterholes in the Todd River system, and Fringe Lilly Gorge waterhole in the Hugh River section of the Finke system.

Large Turbid Near-Seasonal Lowland Waterholes is a wetland type based on long waterholes in the Mitchell Grass Downs bioregion in the north-east of the arid NT, including the Barkly Tablelands. Virtually all rainfall occurs in summer and the bulk is associated with monsoonal clouds originating to the north. Annual rain is unreliable but is more reliable than further south in the arid NT. Large river channels traverse the black (or grey) clay plains, with numerous waterholes. Some of the deeper and longer lasting ones are associated with minor rock outcrop, however there are none that are known to be spring-fed. The waterholes which best fit this pattern are in the Georgina River system, with catchments extending north of the arid NT where the monsoon influence is even stronger. The drainage systems associated with the Davenport Ranges, also mainly flow following summer rains, but may be less reliable than in the Barkly tableland. Further collation of stream flow and rainfall records and oral history would allow more detailed hydrological description.

The waterholes in this type are typically highly turbid with a milky grey colour from the 'black soil' of the plains. There are several waterholes that typically hold water through the dry season to the next wet and a few that hold water through droughts, for two or more years of low rainfall. Several may be semi-permanent, such as One Mile Waterhole at Souden, Big Ranken, and Junction Waterholes. Lake Nash Waterhole, although the largest, is not the longest lasting and dries out in many years, possibly due to relatively pervious soils (K.Schwartzkopff pers. comm.)

The majority of the waterholes of this wetland type are heavily grazed at some stage in the dry season. The gentle banks of the waterholes typically support a dense cover of low herbaceous plants, when not disturbed by stock. Two types of floating aquatic plants occur and may be more abundant in waterholes that are fenced from stock: Water Lilies (*Nymphaea* sp.) and the lily-like Marshworts (*Nymphoides* spp.) which have much smaller leaves (or pads) than the lilies. There is anecdotal evidence that the abundance of lilies is decreased by cattle. The waterhole at Avon Downs homestead is fenced from stock and has an abundant cover of lilies (P.Latz pers. comm.). The waterholes are tree lined, predominantly by *Eucalyptus barklyensis* (Barkly Coolabah) with occasional Bauhinia trees (*Lysiphyllum gilvum*). Shrubs, predominantly *Acacia farnesiana* are mixed in with the trees. In some places the noxious weed *Parkinsonia aculeata* is an element of the shrub layer, with the potential to form dense thickets. Another noxious weed, Noogoora Burr (*Xanthium strumarium* s.lat.) has apparently greatly increased in 2000-2001, and is widespread, with dense thickets in many places.

Temporary (Generally Dry) Lowland Waterholes includes a broad range of sizes and topographies of waterholes. Various subdivisions could be made based on the basis of size, depth, substrate and fringing vegetation and further analysis of survey data from the inventory could assist with this. This category includes some large waterholes in the mid-lower Finke River that can last well over a year, such as Snake Hole. It is possible that some may be 'long-term' rather than temporary, if they are often refilled by river flow without totally drying out. In which case, an additional wetland type could be defined to accommodate them. Some waterholes periodically get filled with sediments, only to be scoured out in subsequent floods. The intensity and duration of rain and the vegetation cover in the catchments both influence in-filling and re-formation of these waterholes, that are temporary not only in the sense of inundation (G. Ride pers. comm. and Unmack 2001a). Good examples are the waterhole in Trepkina Gorge, Long Waterhole near the homestead of Conniston Station and a waterhole recorded by Strehlow near Idracowra homestead. The latter two have been relatively shallow due to sediments for decades but were previously recorded as significant waterholes.

Temporary Lowland Channels

Watercourses in lowlands tend to be wide, sometimes with deep channels, and typically have sandy beds, but substrates may also be clay, loam, gravel, pebbles or bedrock. Some lowland watercourses have coarse gravel or pebble substrates where they travel between or emerge from rocky uplands. In general, lowland water courses are lined by relatively tall trees dominated by *Eucalyptus* species; however, there are also some minor lowland channels, and some with no fringing woody vegetation. Seven separate types of lowland channels are recognised:

- WL2001 Major Wooded Watercourses
- WL2002 Minor Lowland Wooded Watercourses
- WL2003 Melaleuca Dominated Lowland Watercourses
- WL2004 Acacia Dominated Lowland Watercourses
- WL2005 Unwooded Lowland Watercourses
- WL2006 Braided Channels
- WL2007 Highly Saline Channels

Major Wooded Watercourses: in most of the arid NT, River Red Gums (*Eucalyptus camaldulensis*) dominate most major drainage lines and many minor ones. Some drainage lines are fringed by Coolabah (*E. coolabah* subsp. *arida*) and occasionally by Bastard Coolabah (*E. intertexta*). Bean Trees (*Erythrina vesperilio*) are also common on river banks northwards from the MacDonnell Ranges, but never as

dominants. Rivers in the Mitchell Grass Downs and Channel Country bioregions generally have clay or loamy clay soils. Major rivers in the Davenport Ranges have long reaches between rocky ranges, but not in gorges, and the river beds are pebbled. Water courses in the Mitchell Grass Downs Bioregion are predominantly fringed by *Eucalyptus barklyensis* (Barkly Coolabah) with occasional Bauhinia trees (*Lysiphyllum gilvum*). A small proportion of the minor creeks are dominated by *Acacia stenophylla* (River Cooba). Small side or annabranh channels occur but are generally not extensive and are not described as a separate type. Also, it is quite common for major river channels to divide for several hundred metres or more and then rejoin.

Minor Lowland Wooded Watercourses: are distinguished from major wooded watercourses on size and have smaller trees, narrower and shallower channels.

Melaleuca Dominated Lowland Watercourses: are channels in which Melaleuca species dominate, without an overstorey of trees. The main examples of this type are in watercourses flowing out from the Davenport and Murchison, where *Melaleuca dissitiflora* dominates many minor lowland channels and some sections of major watercourses, including at either end of wooded waterholes.

Acacia Dominated Lowland Watercourses: in the east of the arid NT there are extensive areas dominated by low woodland/shrubland of Gidgea (*Acacia georginae*), particularly in the Channel Country Bioregion. Minor drainage lines in these landscapes are typically lined with Gidgea. In the Barkly Tableland there are a few minor lowland creeks in which River Cooba (*Acacia stenophylla*) is the dominant overstorey. A small number of minor lowland creeks in the Toko Ranges are dominated by Mineritchie (*Acacia cyperophylla*). This species also dominates a few minor upland creeks in the small part of the Stony Plains bioregion that occurs in the arid NT.

Unwooded Lowland Watercourses: there are various areas where lowland channels have no fringing trees or shrubs. These are typically relatively minor channels though grassy or stony plains and have relatively minimal biological values as wetlands.

Braided Channels: there are very few examples of braided channels in the arid NT but there is one area of sufficient extent to warrant inclusion as a wetland type. The Lander River floods out between the end of its major channel at about Curlew waterhole and the large basin of Lake Surprise. The floodout consists of numerous minor and interconnected channels across a fairly narrow floodplain of about 1 to 1.5km wide and extends for about 15km (D.Langford pers. comm.). Larger channels reform and dissipate along the route to Lake Surprise.

6.11 Springs

Springs occur in many parts of the arid NT, and though not common, they play an important role in wetland creation and longevity of inundation. Most permanent waterholes are spring fed. Many salt lakes have temporary springs on their edges and some also have groundwater discharge under the lakebed. Indeed much of the surface salt can be from this source. 'Springs' is used in a broad sense to include any groundwater discharge that reaches the surface. It includes those that produce flowing water, only a trickle or only saturated soils. Those that are not flowing are often called soakages or seepages and Bayly (1999) discusses their traditional importance as drinking water for desert Aborigines. Some springs are permanent, with relatively constant output flow. Others vary dramatically in volume, at times producing flowing streams and at other times dwindling to a seepage or drying up completely.

Spring waters are produced from a wide variety of rocks and sediments including elevated mountain ranges and relatively shallow surface rocks such as calcrete. Water may be stored in pores in the rock (e.g. sandstones) or in cracks and joints in otherwise impervious rocks (e.g. quartzites). Cracks in calcareous rocks such as limestone, dolomite and calcrete are widened as groundwater dissolves CaCO₃ out of the rock. Calcrete groundwater is typically saline and calcareous but is sometime fresh. Some springs rise from deeper pervious rock that is confined by overlaying impervious rock. Natural springs can occur where there are cracks in the overlaying formations and are called artesian springs. The associated water bearing rocks are called confined aquifers. The largest and best known confined aquifer in Australia is the Great Artesian Basin (GAB), which has areas of both discharge and recharge in the arid NT (south east corner). However, it is quite certain that there are no GAB springs on the scale of the magnificent Dalhousie Springs in northern South Australia, where vast volumes of hot water pour out

through various springs and have produced mounds metres high. The water pools at Dalhousie support endemic fishes as well as a great diversity and abundance of wetland plants and birds. Among the other Great Artesian Basin Springs, most of which are towards the basin edge, are some on the northern fringe of the Simpson Desert in Queensland. Most of these are relatively minor and do not produce a surface flow of water and have not produced mounds (R.Fairfax pers. comm.). It is possible that there are also minor springs that form seepages in the NT portion of the Simpson Desert.

Those springs that yield flowing water for great lengths of time are of great biological importance and clearly warrant inclusion in this inventory of wetlands. Those that only produce seepage or only flow for a few weeks or months following rain have less certain status as wetlands, and do not often support populations of water dependent plants or animals. However, some seepage areas do have a unique dependent flora, such as *Hydrocotyle D62620 Harts Range* and some of the ferns found only in seepage areas in moist gorges.

There are various ways of categorising springs. In the classification of arid NT wetlands they are divided into upland and lowland, flowing versus non-flowing, saline and semi-saline versus fresh and also into categories of longevity and other aspects of landform: degree of shading and whether or not in a drainage line. This results in a relatively large number of spring types, however, despite relatively little documentation of individual springs in some types, each type is felt to have an identifiably different ecological character as described below. Details of aquifer type are not included in the definitions of wetland type, although they may be important for detailed understanding of the hydrology of associated wetlands. There is some overlap between some spring wetland types and other wetland types, however, springs need to be treated separately because of their relative longevity in an arid landscape. Springs that discharge directly into waterholes are not included.

There are numerous anecdotal reports of daily variations in the flow rate of natural springs; sometimes with suggestions that this is due to effects of the moon's gravity on ground water. The very slow rates of water movement through most aquifers make this explanation unlikely to be correct. The influence of changing atmospheric pressure and changes in evapotranspiration are more likely explanations (R.Read pers. comm.)

Upland Springs

The following types of springs in upland terrain have been defined as wetland types:

- SU1101 Permanent Running Upland Freshwater Springs
- SU1102 Generally Wet Running Upland Springs (non-permanent)
- SU1211 Temporarily Running (generally dry) Freshwater Upland Springs
- SU2111 Permanent Sheltered Freshwater Minor Springs and Seepages
- SU2112 Non-permanent Sheltered Freshwater Minor Springs and Seepages
- SU2201 Generally Wet Minor Springs and Seepages in Exposed Upland Terrain
- SU2202 Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry)

Permanent Running Upland Freshwater Springs: a small number of springs produce a permanent running spring fed stream. There is at least one in the Chewings Range of the West MacDonnell Ranges, one in the Mount Palmer Ranges in the far west of the MacDonnell Ranges and possibly two in the Treuer Range in the north east of the Burt Plain Bioregion. Those in the greater West MacDonnells support rare and relictual plants. An aquatic invertebrate, the Water Penny (*Sclerocyphon fuscus*) also occurs in these wetlands. It is considered relictual in inland Australia, where it is only known from a few very low salinity spring-fed pools and streams in the arid NT.

Generally Wet Running Upland Springs (non-permanent): there are a number of upland springs which produce creek flow that are not permanent but may be more often flowing than not. Most occur in or adjacent to creeks. A range of water chemistry (salinity and calcareousness) is included since there is insufficient data about the associated wetland values to define separate wetland types on water chemistry. There are a few long-term springs in the Dulcie Ranges that produce flowing water, such as at Old Huckitta Homestead.

Temporarily Running (generally dry) Freshwater Upland Springs: includes a range in water chemistry. Most examples are in or adjacent to creeks. Many other upland springs exist, but for most there is insufficient information about the strength and reliability of flow to allocate them to specific wetland types. There are several springs that may run for many years, but there is insufficient data to determine if they are 'generally wet' or temporary (generally dry); for example some in the Anmatjirra Range and Yundurbulu Range. Many are grouped in the broad wetland type 'SF1.1 Running Upland Freshwater Springs'.

Permanent Sheltered Freshwater Minor Springs and Seepages: minor springs and seepages are those which typically do not flow at a sufficient rate to create 'running water'. Those that are permanent and emerge in shaded gorges and canyons in sandstone and quartzite ranges are very significant for regional biodiversity. They support various relictual ferns that require relatively mesic environments. These ferns are rare in arid Australia, being restricted to these environments, but most species are common in wetter coastal areas. Different species and groups of species are found in each moist gorge, and it is not known the extent to which this is a result of random survival and dispersal histories as opposed to habitat differences between gorges. The terms gorge and canyon are used quite loosely and interchangeably in central Australia.

There are several species of ferns, which in central Australia are restricted to mesic environments (about 11 species). Most are only known from relatively deep shaded gorges, but a few occur in association with running streams in moderately shaded gullies. Some grow in areas of saturated soil, while others are only known from seepage areas on rock walls with typically just a few plants. These latter are at the smallest end of the size spectrum of wetlands, but the dependence of the ferns on free water justifies their inclusion as wetlands. A few species may not require seepage, only deep shade, and so are not considered to be wetland plants nor indicators of micro-wetlands.

Most of the examples of this wetland type are in the MacDonnell Ranges Bioregion (West MacDonnells and George Gill Range), with one example known in the north east of the Great Sandy Desert Bioregion (one species only) and several examples in the Burt Plain Bioregion (Dulcie Ranges – one species only). There are none in the Davenport Murchison Ranges Bioregion despite suitable shaded gorges and relatively high rainfall and humidity. This is an indication that groundwater discharge in the gorges there is not sufficiently reliable to sustain any relictual fern species. By far the greatest concentration of wet gorges is in the George Gill Range; however, the greater west MacDonnell Ranges area has a higher diversity of mesic fern species (10 compared to 7 in the George Gill Range).

Non-permanent Sheltered Freshwater Minor Springs and Seepages: after rains there are many more seepage areas and minor springs in gorges as well as other parts of the landscapes. These may be important contributors to the longevity of some pools, but they do not have a particular suite of characteristic plants.

Generally Wet Minor Springs and Seepages in Exposed Upland Terrain: these are areas of reliable groundwater discharge in upland areas, but not in sheltered gorges and typically do not produce running water. This wetland type includes minor springs and seepages in drainage lines as well as others. It includes very minor soakages in sandy creeks and those that form small pools in rockier areas. Few such wetlands are documented sufficiently to distinguish permanent from other generally wet seepages. A considerable range in salinities is likely. At least one of those recorded has formed a low mound of concreted organic matter adjacent to a creek, with some surface salt crystals. This example, in the Yundurbulu Range, generally has an associate pool, with dense bullrushes (*Typha domingensis*), but in droughts, it is reduced to a soakage. The presence of some minor spring may only be evident in the vegetation, with species such as *Juncus A87739 MacDonnell Ranges* (a water rush), which requires good water supplies but not necessarily saturated surface soils.

Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry): many springs and seepage areas appear after heavy regional rains and may last from weeks to months. This wetland type includes temporary minor springs and seepages in drainage lines and on hill sides, the latter typically being on the mid-lower slope above a drainage line. A considerable range in salinities is likely.

Lowland Springs

The following types of springs in lowland terrain have been defined as wetland types:

- SL1111 Generally Running Freshwater Springs in Lowland Drainage Lines
- SL1112 Temporary (generally dry) Running Freshwater Springs in Lowland Drainage Lines
- SL1121 Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines
- SL1122 Temporary (generally dry) Running Saline/Semi-saline Springs in Lowland Drainage Lines
- SL2111 Freshwater Minor Springs and Seepages in Lowland Drainage Lines
- SL2121 Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines
- SL2211 Freshwater Lowland Minor Springs and Seepages not in Drainage Lines
- SL2221 Long-term Springs on Salt Lake Margins and Lake Beds- Saline/Semi-saline
- SL2222 Temporary Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline (generally dry)
- SL2223 Mound Springs - Saline/Semi-saline
- SL2224 Other Saline/Semi-saline Lowland Springs

Generally Running Freshwater Springs in Lowland Drainage Lines: there are two permanent examples of this type which produce two of the permanent large waterholes in the Finke River system: Running Waters and Illara Waterhole. Both emerge in broad sandy sections of river that are not in gorges and produce flowing surface water, for up to 2 km at Illara. A much smaller spring in Wallis's Paddock in the East MacDonnell Ranges generally produces running water and is nearly 1 km from the base of a large quartzite range, but it is not associated with a major sandy wooded watercourse, unlike Illara and Running Waters.

Temporary (generally dry) Running Freshwater Springs in Lowland Drainage Lines: there are no well documented examples of this type.

Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines: there is at least one good example of this type, which is in a minor tributary of the Finke River in the Finke bioregion. The spring is long-term and normally, surface water flows for several hundred metres, however, in the early 1970s discharge reduced to the point where there was no surface flow. Despite its unusual character, no rare plants have been recorded there.

Temporary (generally dry) Running Saline/Semi-saline Springs in Lowland Drainage Lines: there are no well documented examples of this type.

Freshwater Minor Springs and Seepages in Lowland Drainage Lines: there are probably various wetlands created by groundwater discharge in this category, some of which may be important for regional biodiversity.

Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines: this type incorporates a range of reliability/longevity. One such spring, in a tributary of the Finke River in the Glen Helen area, has formed a mound of calcified organic matter on the banks of a minor lowland creek. The creek is close to low hills and is arguably upland or intermediate. Another spring, several kilometres south, in the Finke River south of Glen Helen Gorge, has the rare Bladey Grass (*Imperata cylindrica*). Salinity has been recorded as 1350 ppm total dissolved solids, which is semi-saline under the definitions adopted for arid NT wetlands. A third spring (or springs) in the same area emerges in a pool on the edge of 2 Mile Waterhole and so does not qualify as a spring wetland type, only as a characteristic of a permanent waterhole wetland. The salinity of the groundwater at 2 Mile Waterhole has been recorded as 11,000 ppm TDS. A smaller example is Bitter Springs in the East MacDonnell Ranges, which is smaller in volume and less reliable than the one at 2 Mile Waterhole, but was important as a water supply to early gold miners at the Arltunga gold fields.

Various springs in the Palm Valley area are arguably in this category but might alternatively be considered upland or intermediate. They are very important for regional biodiversity, sustaining most of the population of the rare endemic palm *Livistona mariae subsp. mariae*, the only arid NT population of the sedge *Eleocharis geniculata* and one of the main arid NT populations of two grass species *Imperata cylindrica* and *Phragmites australis*.

Freshwater Lowland Minor Springs and Seepages not in Drainage Lines: flow is generally minor and includes isolated soaks in sand country and at the base of granitic ranges, some of which only marginally qualify as wetlands. No subdivision is made on longevity due to very little documented data on occurrence and nature, although these would be well known to traditional Aborigines and to some stockmen.

Long-term Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline: there are long-term springs on the edge of salt lakes. The only one surveyed for its wetland values is on the edge of one of the Karinga Creek system of saline lakes, in the Finke Bioregion, with water emerging from the edge of the calcrete plateau which fringes the lake. Although semi-saline (2430 μ S/cm), it is important for stock watering, and unrestricted access by stock is the main impact on natural values. In addition to broad areas of saline ground water discharge, some salt lakes have surface springs in the lake bed, with several recorded for Lake Amadeus (Jacobson 1996), where they are relatively low in salinity (90,000 ppm) compared to the surrounding hypersaline brines (240,000 ppm TDS).

Temporary Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline (generally dry): following high regional rainfall there are numerous temporary saline springs on the edges of large salt lakes. Some are assumed to be discharge from shallow calcrete aquifers in paleodrainage lines.

Mound Springs - Saline/Semi-saline: there are some springs in the NT that have water with high mineral content and which form low mounds or banks composed of solids deposited by evaporating water and concreted organic matter and wind blown soil. Springs of this nature in the area between Glen Helen Gorge and Ormiston Gorge have been referred to as 'mound springs' (anon 1972, Pitts 1994). These are not on the same scale as many of the Great Artesian Basin mound springs, such as at Dalhousie Springs. One near Glen Helen Gorge emerges from a mound about 2m high. Several other mounds in the same valley are presumed to be extinct springs. Only small volumes of water are produced and the 'mounds' are relatively very small. The water comes from a local aquifer rather than a major sedimentary basin (R.Read pers. comm.). One has formed a distinct mound, rising some 2 metres above a surrounding plain. The other active spring is adjacent to a creek and has a much less pronounced mound; possibly due to erosion during creek floods. A similar spring was observed, during this inventory, at Spring Creek on Conniston Station. This produces flowing water in most years and even when not running still forms a seepage, according to local Aborigines (M.Lines pers. comm.).

Another mound spring is recorded at the eastern end of Lake Amadeus: 'several metres high, encrusted with carbonate' (Jacobson 1996, p. 259).

There was information deduced from a very early Queensland grazing cadastral map, which indicated the presence of a spring on the present day Tobermorey Station in the NT. Other springs marked on the map in Queensland are from the Great Artesian Basin, leading to supposition that there may be undiscovered mound springs in the NT. However, consultation with hydro-geologists from the NT Department of Lands Planning and Environment (P.Jolley and R.Read, pers. comm.) and careful cross-referencing of the old map to modern topographic maps, indicates that the springs in question are from the Georgina Basin and now lie beneath stock dams.

Other Saline/Semi-saline Lowland Springs: this wetland type was created to accommodate any saline or semi-saline springs in lowlands that do not fall into the categories of the specific types such as mound forming springs and springs on the edges of salt lakes. There is little information about any such springs or their biological values. It is unlikely that such springs are of great importance for regional biodiversity, but not impossible. One possible example is Emu Spring near Central Mount Wedge, which has salt tolerant plants and is presumed to emanate from a calcrete aquifer in a paleodrainage line (as described by Wischusen 1998). Emu Spring is mapped (1:250,000 topographic map) as in or near a drainage line, so may be better placed under 'Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines'.

6.12 Subterranean Wetlands

Subterranean wetlands are not explicitly included in our wetland definition for the arid NT but are included in as a wetland type for consistency with the Ramsar classification:

U0001 Underground Waterfilled Spaces in Rock with Macroscopic Invertebrates

Very little is known about these wetlands. What information there is indicates that such environments are widespread even though known limestone caves are small, above the water table, and therefore dry. Sampling of bore waters has confirmed the presence of subterranean macroscopic aquatic invertebrates, typically in calcrete and possibly strongly associated with paleodrainage lines. The presence of large wet caves cannot be ruled out, but it is assumed that small cracks are the main habitat.

6.13 Artificial Wetlands

In the wetlands classification for the arid NT, artificial wetlands are divided according to the source of the water which characterises a place as a wetland. Apart from toxic mine tailings dams, most artificial wetlands increase the availability and reliability of habitats for some species of waterbird and some aquatic plants. Artificial wetlands have been grouped into the following types.

- A1001 Dams Across Watercourses
- A1002 Excavated Dams/Tanks in Swamps and Pans
- A1003 Other excavations: quarries, borrow pits, mine pits
- A2001 Excavated Dams Filled from Bores
- A2002 Built-up Earth Tanks Filled from Bores
- A2003 Minor Overflow from Bores
- A2004 Open Metal/Concrete Tanks filled from Bores
- A2005 Rogue Bores
- A3001 Sewage Ponds
- A3002 Swamps Created/Modified By Treated Sewage
- A4001 Mining Tailings Ponds

Stored rainfall runoff

Dams Across Watercourses: the majority of dams across watercourses are created to store water for stock. A notable exception is the large dam at Jervois Mine at the base of the Jervois Range. Most are temporary but are deep enough to hold water for months or years between rainfall runoff events. Dams across watercourses are generally located in areas of moderate gradient and on small to medium sized watercourses, where water flows are unlikely to break the dam. In the Barkly tableland, there are examples of dams or tanks on relatively flat ground and there are remains of much older stone wall dams, including some across the Georgina River. These were created by Chinese gold miners in transit between the Northern Territory gold fields and Queensland, probably in the 19th century. A few stock dams are sustained by springs and form permanent or semi-permanent water bodies, for example, Black Stump Dam and Craigie Dam on Tobermorey Station and Tourmaline Dam (aka Recreation Dam) on Conniston Station.

Excavated Dams/Tanks in Swamps and Pans: excavated earth tanks, sometimes referred to as dams, are created to store water for stock and are typically in natural wetland basins (swamps or lakes). By increasing the depth of the waterbody in the excavated area, evaporation losses are reduced, and longevity is increased. Excavated material is typically piled up to form an adjacent wall and on gentle slopes may also function as a dam.

Other excavations: quarries, borrow pits, mine pits: any form of human excavation can form a water storage area. Inundation is generally shallow and brief in unplanned water storage due to a small catchment area.

Bore Water

Excavated Dams Filled from Bores: some excavated tanks and dams store surface runoff but are also used to store bore water. Examples in the Hanson and Lander river catchments contribute to the persistence of translocated fishes.

Built-up Earth Tanks Filled from Bores: in predominantly flat areas, there is little concentration of rainfall run-off, and stock water storages are typically elevated earth tanks called ‘turkeys nests’ which are filled from bores.

Minor Overflow from Bores: small swamp areas can form as a result of the overflow of bore water at bores, troughs and next to turkeys nest tanks. These are uncommon and are typically unimportant for wetland plants and animals in the arid NT.

Open Metal/Concrete Tanks filled from Bores: metal and concrete tanks have a smaller surface area than earth tanks but never-the-less support wetland plants such as *Typha domingensis*.

Rogue Bores: there have been several rogue bores in the NT portion of the Simpson Desert, releasing uncontrolled flows of water from the Great Artesian Basin. According to Graham Ride, the most notable rogue bore is McDills No.1 Bore which has sustained a large continuous wetland between sand dunes in the Simpson Desert for many decades. Specific values are undocumented, but the wetland is known to be utilised by waterbirds. This artificial oasis will be much reduced in size now that the bore is rehabilitated. Some controlled flow is to be maintained at the wishes of traditional Aboriginal owners. Other lesser examples are Dakota Bore and Anacoora Bore (G. Ride pers. comm.).

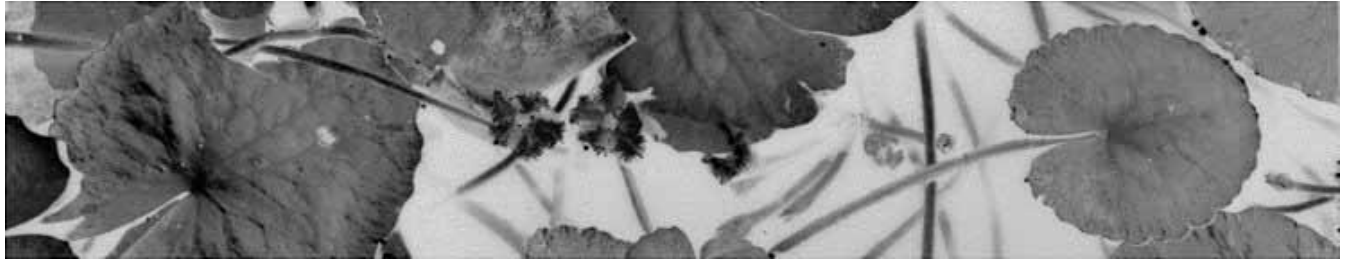
Sewage Water

Sewage Ponds: sewage ponds that treat effluent from larger settlements can cover substantial areas. The largest group, and only one well documented for birds, is the Alice Spring Sewage Ponds. These ponds are regularly used by larger numbers of waterbirds of a great many species.

Swamps Created/Modified By Treated Sewage: the largest and only well surveyed example is Illparpa Swamp adjacent to the Alice Springs Sewage Ponds, where an intermittent/semi-permanent *Typha* Swamp has developed in recent decades. The treated effluent overflows from the treatment ponds into the natural swamp, but is now drained into the outlet creek to reduce mosquito breeding. In natural arid NT wetlands, Bullrushes (*Typha domingensis*) only occur in relatively small areas, generally as fringing vegetation.

Mining Effluent

Mining Tailings Ponds: there are substantial mining effluent storage ponds in the Tanami desert. Details of size of ponds and toxicity levels are unknown, but gold mining effluent ponds at Tennant Creek are reported as causing deaths in waterbirds.



7. Summary of Field Survey

7.1 Ground Survey

The ground survey of wetlands was site based. In most instances one site corresponded to one wetland, but for some large and complex wetlands two or more sites were needed to adequately sample the range of wetland types present.

The ground survey sites are broadly divided into rapid assessment sites, where core data for the inventory were collected, and detailed sites, where more detailed data were collected on vegetation and, where present, aquatic invertebrates, fish and wetland birds.

Rapid assessment sites generally took between 15 and 30 minutes for one person to survey. Detailed sites take two or more people one to two hours.

Sixteen wetland dedicated field trips were undertaken, covering most of the geographic extent of the study area and adequately sampling a representative set of wetlands. The sum of staff time on the trips was 350 person days. Due to the long travel times to reach the parts of the inventory area farthest from Alice Springs, where the project team was based, field trips were generally of a duration of one to two weeks, with each focusing on a particular area. Some additional sites were surveyed on day trips from Alice Springs and by staff on other field trips. The total number of ground survey sites was 422, and the number in each bioregion is shown in table 12.

Table 12. Number of sites by bioregion.

Bioregion Name (and Code)	No. Of Ground Survey Sites
Burt Plain (BRT)	75
Channel Country (CHC)	22
Central Ranges (CR)	7
Davenport Murchison Ranges (DMR)	33
Finke (FIN)	57
Great Sandy Desert (GSD)	59
MacDonnell Ranges (MAC)	10
Mitchell Grass Downs (MGD)	39
Simpson-Strzelecki Dunefields (SSD)	52
Stony Plains (STP)	21
Tanami (TAN)	48

Aquatic invertebrates were collected at 85 sites, and fishes were collected at 53 sites. Plant species data were recorded at 321 sites.

A summary of the dates, itineraries and personnel of each field trip is attached as appendix 7. A chronological list of all ground survey sites is included in volume 2.

The rainfall preceding and during the survey period was well above average. This meant that most wetlands visited were either inundated or had vegetation resulting from recent inundation. This was valuable, both in identifying the occurrence of wetlands and in assessing their general ecological character. However, the same wet conditions severely impeded access and increased travel time between sites. Some roads were washed out. Many wetlands that were targeted for survey were well away from any roads, and the bogging of vehicles was common.

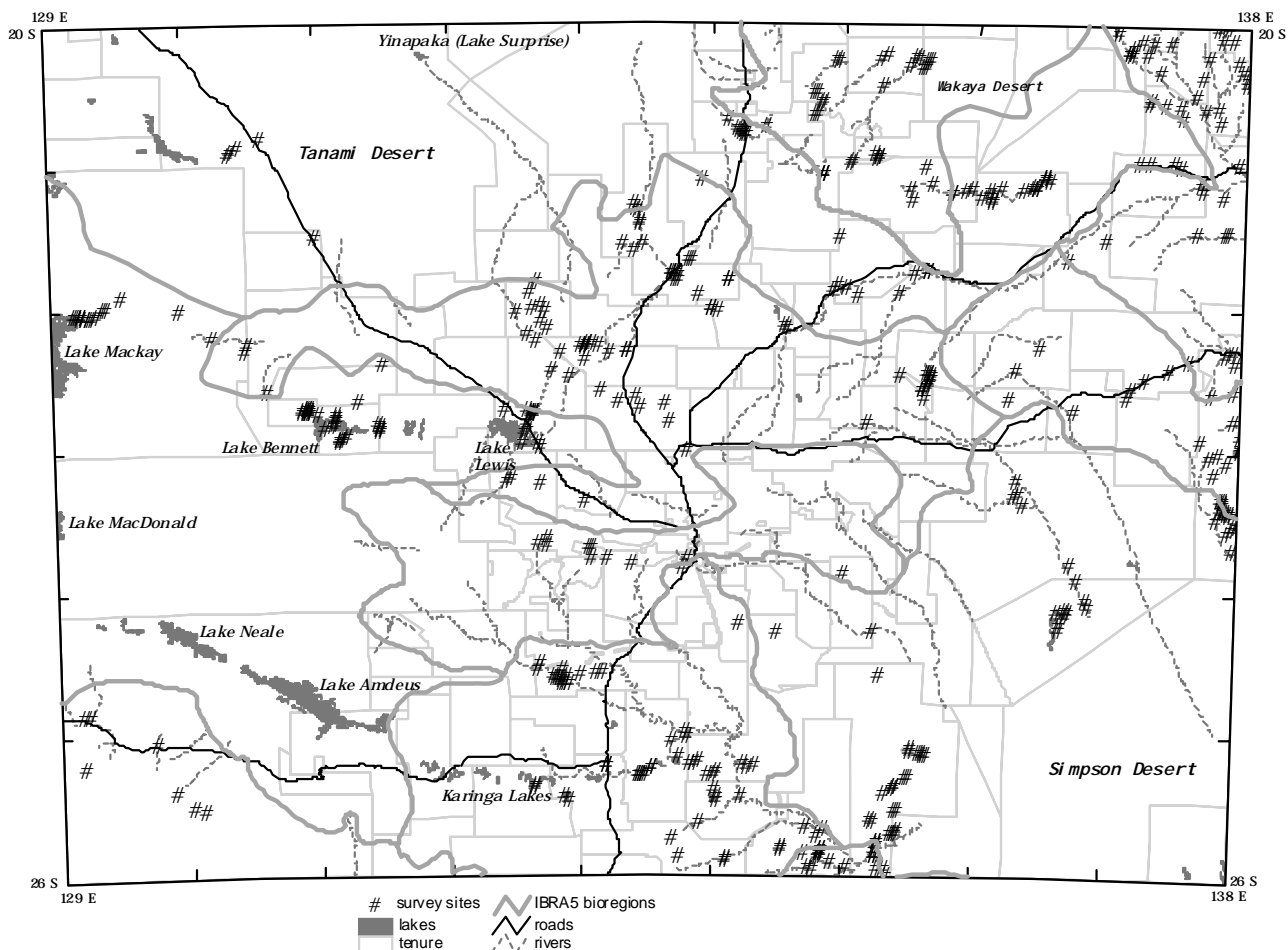


Figure 11. Ground survey site locations.

Water Chemistry

Electrical conductivity was measured for 124 sites. All samples were measured using digital conductivity metres. Bottled samples for 116 sites were measured in the laboratory, mostly in the Water Resources branch laboratory, but some samples were measured using cheaper conductivity metres in the Parks and Wildlife laboratory. The other sites were measured in the field. For a small number of sites, total dissolved salt (TDS) content and major ion concentrations were determined in the Darwin laboratory of the Water Resources branch of the Department of Lands Planning and Environment.

Conductivity values ranges from negligible values ($< 100 \mu\text{Scm}^{-1}$) to highly saline. Of the 124 sites, 97 had a water conductivity of $< 1,600 \mu\text{Scm}^{-1}$ when sampled. There were 14 sites that were semi-saline according to the criteria we have adopted here ($> 1,600$ and $< 4,600 \mu\text{Scm}^{-1}$), and there were 13 sites that were saline ($\geq 4,600 \mu\text{Scm}^{-1}$). The highest surface water conductivity value was $58,600 \mu\text{Scm}^{-1}$ from Lake Bennett. Water from a soil pit (brine) in Lake Bennett had a value of $156,000 \mu\text{Scm}^{-1}$. Jacobson (1996) reports brine values from the Curtin Springs area salt lakes as containing between 350,000 and

400,000 mg/l TDS, noting that these are possibly the saltiest lakes in Australia. The conductivity value of 350,000 TDS is not given, but the salinity is presumed here to be considerably greater than our brine sample from Lake Bennett.

Water pH was measured for 80 sites, predominantly from bottled samples. These were analysed with an accurate digital pH metre in the Alice Springs laboratory of the Water Resources branch of the Department of Lands Planning and Environment. The majority of sites had neutral or nearly neutral water when sampled (pH 6-8, 68 sites). Only two sites had an acidity of less than pH 6. These were both wetlands which had substantially dried back and were heavily trampled by cattle drinking the water. The lowest pH (4.2) was at a site with water of only 2 cm depth. Ten sites had water pH greater than 8. Most of these had some aquifer discharge contributing to the surface water, including springs and salt lakes. The highest pH was 9.6.

7.2 Aerial Survey

Two wetland dedicated aerial surveys were undertaken. The first covered parts of the Finke Bioregion on 21 July 2000 and was essentially a reconnaissance flight, but included collection of valuable information for the mapping of wetland types. The second, on 5th and 6th September 2001, was focused on counting waterbirds on Lake Mackay but also included a general wetland survey across parts of the Tanami, Great Sandy Desert and Burt bioregions, with aerial bird counts at Lake Surprise, Lake Lewis and various lakes in the Central Mount Wedge area.

Additional aerial survey was conducted during the Feral Camel Survey program conducted in August and September 2001 (Edwards *et al.* 2004). This involved logging the occurrence of wetlands and categorising them according to the broad types discernable from the air. The results of this component of the wetlands inventory are presented in the mapping chapter.

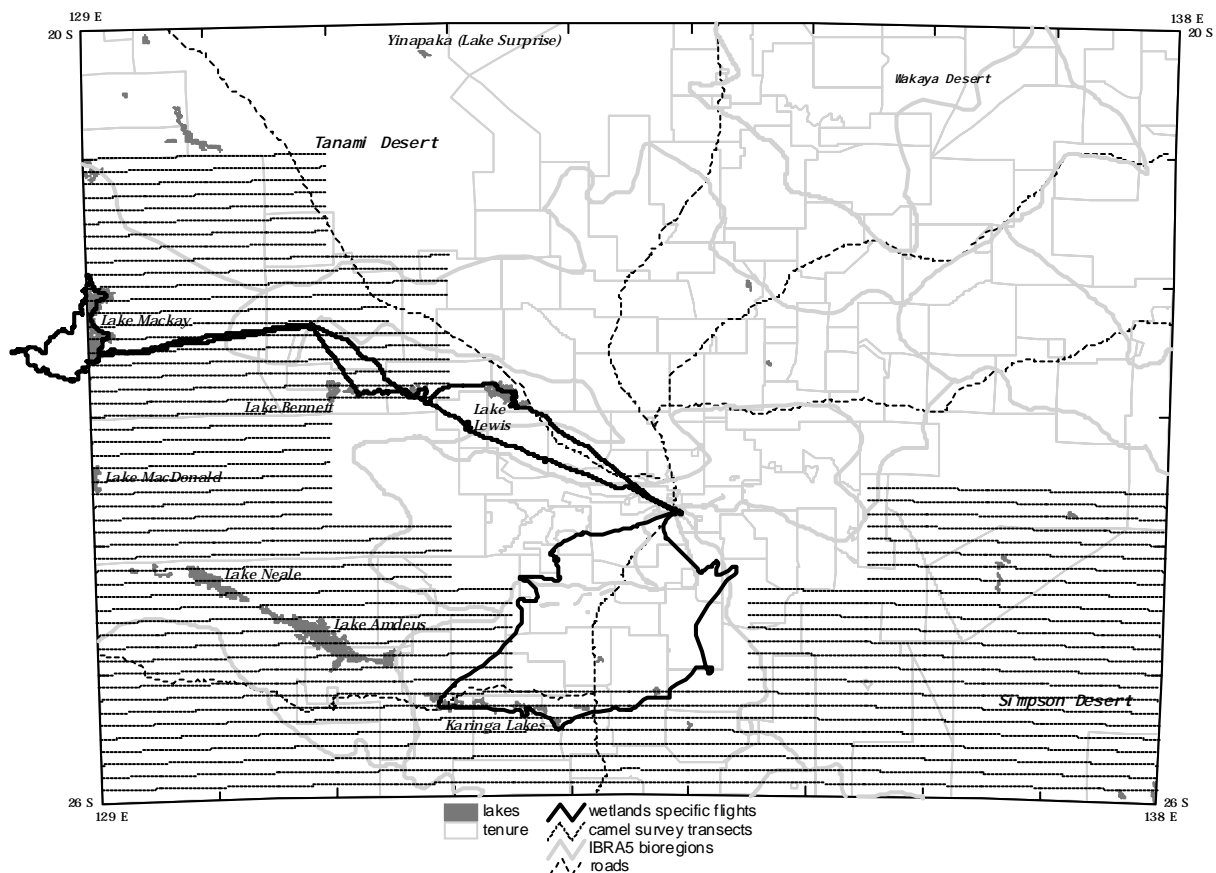


Figure 12. Aerial survey flight paths: wetlands specific and camel survey.



8. Wetland Birds in the Arid NT

Scope

This section is a review of wetland birds of the arid NT based on existing data and new data collected by and during the wetland inventory. The section provides a summary of all wetland birds recorded from the arid region of the Northern Territory. We summarise information on the frequency and seasonality of occurrence in the region, taxonomic status, conservation status, and ecology. Based on the survey data, wetlands of significance to birds are identified.

8.1 Definitions

For the purposes of this study, a wetland bird is defined as one for which wetlands are important for at least one stage of its life cycle (e.g. breeding, feeding, roosting). This definition includes species which are not obligate wetland birds but which use them when available (i.e. Oriental Pratincole, Australian Pratincole). However, we did not include species purely on a taxonomic basis, e.g. Bush Stone-curlew and Inland Dotterel were not included, even though both species are in the taxonomic group called shorebirds.

Each wetland bird species was placed in one of four categories of occurrence as defined below:

Resident - some individuals present in region throughout the year. Occurrence in dry periods may be confined to the few places with permanent water (e.g. Alice Springs Sewage Ponds).

Sporadic – species that is frequently present in the region, but occurrence dependent on unpredictable factors (e.g. rainfall) and, in most species, not well understood. Often irruptive species that when present occur in large numbers. Further research may show some of these species to be resident.

Summer visitor – migratory species that is regularly present in the study area between late August and early April.

Vagrant – occurs irregularly in small numbers (usually one) well outside its normal range. This category includes migratory species.

These categories are a simplistic but useful representation of the occurrence of wetland birds in the study region. This approach is necessary due to a lack of comprehensive records of species occurrence. The remoteness of much of the study area, the highly unpredictable nature of rainfall in the arid NT and the associated unpredictability of habitat availability for wetland birds are underlying causes of the lack of data.

The distribution of non-vagrant species was defined as widespread or patchy. Those species classed as widespread are recorded from sites located across the study area. In contrast, species classed as patchy are known from sites clumped in a few regions of the study area.

Taxonomy and nomenclature used in this report are based on Christidis and Boles (1994). Biological and life history information is based on *Handbook of Australian, New Zealand and Antarctic Birds* Volumes 1A, 1B, 2 and 3. Those readers who wish to pursue alternative common names are referred to the *Readers Digest Complete Book of Australian Birds*.

8.2 Methods

Data on wetland birds of the arid NT were obtained from previous studies, surveys carried out during the study period but not connected with the wetland inventory and from surveys carried out as part of the wetland inventory.

All point data locations were plotted out on a map of the study area for each species. These maps, coupled with other information recorded with some observations, were the basis for the analysis of distribution. For a number of wetlands, total counts of waterbirds present at the time of observation were available.

Details of each data source are provided below.

Existing Information

Existing information was available from several sources as detailed below.

Records in the NT Fauna Atlas database (incorporating the Biological Records Scheme, BRS) of the Parks and Wildlife Commission of the NT.

Unpublished sightings by bird watchers from 1978 onwards.

Records present in the literature including scientific papers (e.g. Whitlock 1924, Fleming 1987) and government reports.

Other Bird Surveys

Data were obtained from two other major surveys that overlapped with the wetland inventory as detailed below.

Survey data collected during the Birds Australia 'Atlas of Australian Birds' project and supplied by Rory Poulter, Database Custodian. Data consist of 60,000 records from 5,000 surveys carried out between August 1998 and October 2001.

Sightings collected during the PWCNT biological survey of the Finke bioregion from March to November 2001. Although the survey did not target wetlands, some of the systematic survey sites were in wetlands, plus all incidental sightings of wetland birds were recorded.

Arid NT Wetland Inventory Bird Surveys

During the course of the wetland inventory, birds were surveyed using two methods. First, ground-based and/or boat-based surveys (2 sites) were carried out at most sites, although this method usually did not include the complete area of each wetland. In general, waterbird counts were centred at the same sites as plant surveys but generally covered larger areas. Birds were identified using binoculars and occasionally a telescope. Observations at a majority of sites were by Barnetson, using a pair of Bushnell 8×35 binoculars.

Aerial surveys of significant wetland sites were carried out from a fixed-wing aircraft on 5 and 6 September 2001. Sites covered included Lake Mackay, Lake Surprise, and Lake Lewis. The methodology used for these surveys was similar to that of previous surveys in the Top End of the Northern Territory (Jaensch 1994) and involved multiple traverses of waterbodies as required to count observed flocks of birds and not on a systematic sampling grid. The majority of observations and identifications were by Ray Chatto (PWCNT).

The number of each species of wetland bird was recorded and whether or not they were breeding, indicated by nests eggs or live young. The field proforma includes a checklist of species considered to be wetland birds that are known from the inventory area. Also the start and finish time of the observation period and the size of the area observed were recorded, where observations were a result of time dedicated to bird survey as opposed to incidental observations during other survey tasks.

Limitations in the Data Set

The aim of the study was to conduct an inventory of the wetlands of the arid NT. Although wetland birds are recognised as an important component of the biodiversity of many of the sites visited, sufficient time and resources were not generally available to thoroughly survey this group. As a consequence, detailed information on species composition and abundance is only available for a handful of sites. At many sites, bird counts were either not done or only carried out for a portion of the wetland. The amount of time spent carrying out aerial surveys was low, and this component of the study probably did not coincide with peak bird numbers.

As a result of the above limitations, we have exercised considerable caution when both discussing the importance of wetlands and comparing our data with those of previous research.

Nevertheless, this is the most comprehensive collation and analysis of wetland birds in the arid NT and draws on significant new data collected for some sites.

8.3 Species Richness

Regional Scale

A total of 95 wetland bird species are recorded for the study area consisting of eight orders from 20 families; as listed in table 13. The total includes 57 species that are resident or occur sporadically in the study area, six species that migrate to the study area each Southern Hemisphere summer and 31 species considered to be vagrants (table 14), some of which have been recorded only once. We consider it is unlikely that further non-vagrant species will be recorded from the study area; however, new vagrants are likely to appear periodically.

Of the 57 resident/sporadic species, the groups with the most species are ducks and swans (11 species), crakes and rails (8 species), and herons and egrets (6 species). The vagrant species are mostly shorebirds particularly sandpipers (17 species). These species are infrequent visitors that most likely occur in the arid NT only after being blown off course or when resting during migration from Northern Hemisphere breeding sites to wintering sites in southern coastal Australia.

The 95 wetland species recorded for the study area is surprisingly high, especially given previous assertions about the limited significance of arid Australia for wetland birds (e.g. Frith 1982). Species totals are comparable to those recorded from several other regions of Australia. Specifically, Jaensch (1994) located 100 wetland species during a 1993 survey of the sub-humid wetlands of the NT and adjacent parts of Western Australia (between 15 and 20 degrees South). A four year survey of wetlands in south-western Australia in the 1980s recorded 96 bird species (Jaensch *et al.* 1988).

Table 13. List of waterbirds recorded from the study area.

Order & Family	Species	Status	Distribution (ASSP = Alice Springs Sewage Ponds)
Order Anseriformes			
Anatidae (Ducks & Swan)	Plumed Whistling-Duck	breeding resident	Widespread
	Wandering Whistling-Duck	vagrant	Wauchope, Austral Downs, ASSP
	Blue-billed Duck	sporadic: breeding	2 sites incl. ASSP
	Freckled Duck	sporadic	Widespread
	Black Swan	breeding resident	Widespread
	Australian Shelduck	vagrant	1 record - Boggy Hole 1923
	Australian Wood Duck	breeding resident	Widespread
	Pacific Black Duck	breeding resident	Widespread
	Australasian Shoveller	sporadic	ASSP and Newhaven only
	Grey Teal	breeding resident	Widespread
	Chestnut Teal	sporadic	Patchy
	Garganey	vagrant	ASSP
	Pink-eared Duck	breeding resident	Widespread
	Hardhead	breeding resident	Widespread
Order Podicipediformes			
Podicipedidae (Grebes)	Australasian Grebe	breeding resident	Widespread
	Hoary-headed Grebe	breeding resident	Widespread
	Great Crested Grebe	vagrant	3 sites incl. ASSP
Order Pelecaniformes			
Anhingidae (Darters)	Darter	breeding resident	Widespread
Phalacrocoracidae (Cormorants)	Little Pied Cormorant	resident	Widespread
	Pied Cormorant	breeding resident	Widespread
	Little Black Cormorant	breeding resident	Widespread
	Great Cormorant	resident	Widespread
Pelecanidae (Pelicans)	Australian Pelican	resident	Widespread
Order Ciconiiformes			
Ardeidae (Herons & Egret)	White-faced Heron	breeding resident	Widespread
	Little Egret	sporadic	most records at ASSP
	White-necked Heron	breeding resident	Widespread
	Pied Heron	vagrant	2 sites incl. ASSP
	Great Egret	sporadic	Widespread
	Intermediate Egret	sporadic	Widespread
	Cattle Egret	vagrant	2 sites incl. ASSP
	Nankeen Night Heron	resident	Widespread
Threskiornithidae (Ibis & Spoonbills)	Glossy Ibis	sporadic	Widespread
	Australian White Ibis	sporadic	Widespread
	Straw-necked Ibis	sporadic	Widespread
	Royal Spoonbill	sporadic/resident	Widespread
	Yellow-billed Spoonbill	resident	Widespread
Ciconiidae (Storks)	Black-necked Stork	vagrant	3 sites

Order Falconiformes			
Accipitridae (Raptors)	Osprey	vagrant	patchy – mostly MacDonnell Ranges bioregion (Glen Helen, Ormiston, Boggy Hole)
	Swamp Harrier	resident	Widespread
Order Gruiformes			
Gruidae (Cranes)	Brolga	breeding resident	patchy – majority of records in N-E quarter of study region
Rallidae (Crakes & Rails)	Buff-banded Rail	probably resident (specific surveys needed)	patchy – mostly MacDonnell Range bioregion
	Baillon's Crake	possibly resident (specific surveys needed)	patchy - 3 sites in MacDonnell Range bioregion
	Australian Spotted Crake	possibly resident (specific surveys needed)	Patchy
	Spotless Crake	possibly resident (specific surveys needed)	patchy – only 2 recent records (Ilparpa Swamp, Tanami Road); 1923 – Finke River near Hermannsburg
	Purple Swamphen	sporadic	patchy – only on S-W quarter of study region
	Dusky Moorhen	breeding resident	patchy – MacDonnell Range bioregion west of Alice Springs
	Black-tailed Native-hen	breeding resident	Widespread
	Eurasian Coot	breeding resident	Widespread
Order Charadriiformes			
Scolopacidae (Sandpipers & allies)	Swinhoe's Snipe	vagrant	ASSP
	Black-tailed Godwit	vagrant	2 sites incl. ASSP
	Bar-tailed Godwit	vagrant	Alice Springs only
	Little Curlew	vagrant	most records at ASSP
	Whimbrel	vagrant	ASSP only
	Marsh Sandpiper	summer migrant	patchy – all but one record in W of study area
	Common Greenshank	summer migrant	Widespread
<i>continued</i> – Sandpipers & allies	Wood Sandpiper	summer migrant	patchy – most records in West MacDonnell Range & Uluru
	Green Sandpiper	vagrant	ASSP – record not yet vetted by Rarities Appraisals Committee
	Common Sandpiper	summer migrant	Widespread
	Grey-tailed Tattler	vagrant	ASSP, Hermannsburg area
	Ruddy Turnstone	vagrant	ASSP only
	Great Knot	vagrant	ASSP only
	Little Stint	vagrant	ASSP only
	Red-necked Stint	vagrant	W half of study area
	Long-toed Stint	vagrant	ASSP only
	Pectoral Sandpiper	vagrant	4 sites incl. ASSP
	Sharp-tailed Sandpiper	summer migrant	Widespread
	Curlew Sandpiper	vagrant	W half of study area
	Broad-billed Sandpiper	vagrant	ASSP
	Ruff	vagrant	2 sites incl. ASSP
	Red-necked Phalarope	vagrant	ASSP only

Rostratulidae	Painted Snipe	vagrant	ASSP, andado Station, Tanami Road
Recurvirostridae (Stilts & Avocets)	Black-winged Stilt	breeding resident	Widespread
	Banded Stilt	sporadic, breeding	patchy – most records from large waterbodies in Great Sandy Desert bioregion
	Red-necked Avocet	breeding resident	Widespread
Charadriidae (Plovers & allies)	Pacific Golden Plover	vagrant	ASSP only
	Grey Plover	vagrant	ASSP only
	Red-capped Plover	breeding resident	Widespread
	Greater Sand Plover	vagrant	ASSP only
	Oriental Plover	summer visitor	Widespread
	Black-fronted Dotterel	breeding resident	Widespread
	Red-kneed Dotterel	breeding resident	Widespread
	Banded Lapwing	breeding resident	Widespread
	Masked Lapwing	breeding resident	Widespread
Glareolidae (Pratincoles)	Oriental Pratincole	sporadic	patchy
	Australian Pratincole	breeding resident	Widespread
Laridae (Gulls & Terns)	Silver Gull	sporadic	Widespread
	Gull-billed Tern	sporadic: breeding	Widespread
	Caspian Tern	sporadic	patchy – isolated sites in E of study area
	Whiskered Tern	sporadic	Widespread
	White-winged Black Tern	vagrant	ASSP only
Order Passeriformes			
Meliphagidae	Yellow Chat	status uncertain	patchy – north-east corner of study area, Simpson Desert and ASSP
Motacillidae	Grey Wagtail	vagrant	1 record, Simpson's Gap 1999
Sylviidae	Clamorous Reed-Warbler	resident	patchy – confined to S of study area
	Little Grassbird	resident	patchy – 3 sites incl. ASSP
	Golden-headed Cisticola	resident	patchy – most sites in Alice Springs region, plus 3 other sites

Table 14. Taxonomic groups of wetland bird species, summarised by categories of occurrence in the arid NT. note: the resident and sporadic are both non-seasonal and are combined in this table due to insufficient data to determine the correct category for some species.

Taxonomic group	No. Species			Total
	Resident/ Sporadic	Summer migrant	Vagrant	
Ducks and swans	11	0	3	14
Grebes	2	0	1	3
Darters	1	0	0	1
Cormorants	4	0	0	4
Pelicans	1	0	0	1
Hérons and egrets	6	0	2	8
Ibis and spoonbills	5	0	0	5
Storks	0	0	1	1
Raptors	1	0	1	2
Cranes	1	0	0	1
Crakes and rails	8	0	0	8
Sandpipers and allies	0	5	17	22
Painted Snipe	0	0	1	1
Stilts and Avocets	3	0	0	3
Plovers and allies	5	1	3	9
Pratincoles	2	0	0	2
Gulls and terns	4	0	1	5
Passerines	4	0	1	1
Total	57	6	31	95

Local scale

Local species richness varied greatly across the study area. Comparison among sites is difficult as a consequence of great variation in observation effort (number of observation days, time spent and proportion of wetland and surrounding wetlands surveyed). For example, while the Alice Springs Sewage Ponds have been surveyed regularly over a 25-year period, most other significant wetlands have been surveyed only once or twice. Although the Sewage Ponds is an artificial site, it supports a very high richness of wetland birds and acts as a refuge during dry periods. A total of 87 wetland species has been recorded from the Alice Springs Sewage Ponds during the period 1978-2002, whereas a maximum of 29 species was observed during the current survey. During a drought in November and December 1978, 49 waterbird species were recorded at the Sewage Ponds (G.Roberts unpublished data). Among the natural sites, the Snake Creek Floodout System held 36 wetland species during a single survey in November 2001, and 27 species were recorded from the Lake Mackay System during ground and aerial surveys in September-October 2001. Based on wetland surveys elsewhere in arid Australia, both Snake Creek and Lake Mackay supported a relatively high richness of waterbirds, especially considering that most of the data were obtained from a single observation period of a few hours at each site. Numbers of species and counts for selected arid NT sites are presented in table 15.

Table 15. Major sites for wetland birds in the study area, in the inland sub-humid tropics of the Northern Territory and selected other arid sites.

Maximum count is the largest number of birds recorded during a single survey, whereas the number of species for a site incorporates data from all surveys.

Site	No. Species	Maximum Count	Survey Type & Date	Source
Arid NT				
Alice Springs Sewage Ponds	29	2,000	Ground (2001-2002)	This study
Lake Lewis	8	13,170	Aerial (Sept 2001)	This study
Lake Lewis (SE arm and adjacent wetlands)	19	775	Ground (Sept 2000)	This study
Lake Mackay System	27	42,473	Ground and aerial (2001)	This study
Lake Surprise	15	3,417	Aerial (Sept 2001)	This study
Snake Creek Floodout System	36	3,384	Ground (Nov 2001)	This study
Stirling Swamp	15	755	Ground (July 2001)	This study
Epenarra Station wetlands	19	425	Ground (July 2001)	This study
Georgina Downs wetlands	17	500	Ground (August 2001)	This study
Karinga Creek Saline System	15	10,799	Ground (Sept 1989)	PWCNT data
Inland sub-humid tropics of NT				
Nongra Lake	29	1,880	Ground and aerial (1993)	Jaensch 1994
Birrindudu Floodplain	50	8,221	Ground and aerial (1993)	Jaensch 1994
Lake Woods	56	44,132	Ground and aerial (1993)	Jaensch 1994
Eva Downs Swamp	33	3,266	Ground and aerial (1993)	Jaensch 1994
Tarrabool Lake	41	7,263	Ground and aerial (1993)	Jaensch 1994
Corella Lake System	43	12,462	Ground and aerial (1993)	Jaensch 1994
Lake Sylvester System	50	32,198	Ground and aerial (1993)	Jaensch 1994
Lake de Burgh	33	23,219	Ground and aerial (1993)	Jaensch 1994
Arid Australia				
Lake Gregory (WA)	73	650,000	Aerial	Kingsford & Halse 1998
Lake Barlee (WA)	8	380,000	Aerial	Kingsford & Halse 1998
Lake Numalla (QLD)	39	100,000	Aerial	Kingsford & Halse 1998
Lake Wyara (QLD)	31	85,000	Aerial	Kingsford & Halse 1998
Cuttaburra Creek Channels (NSW)	17	133,800	Aerial	Kingsford & Halse 1998
Murrumbidgee/Lachlan confluence (NSW)	28	154,900	Aerial	Kingsford & Halse 1998
Lower Cooper Creek (SA)	55	134,224	Aerial	Kingsford et al. 1999
Lake Hope (SA)	28	28,000	Aerial	Kingsford 1995
Lake Blanche (SA)	26	147,800	Aerial	Kingsford 1995
Lake Eyre (SA)	44	324,989	Aerial	Kingsford & Halse 1998

Note: More recent surveys have increased the numbers of species and peak numbers of birds recorded at some the wetlands above that are outside of the NT (R.Jaensch pers. comm.). For example, Lake Woods, Eva Downs Swamp, Tarrabool Lake, Corella Lake System, Lake Sylvester System and Lake de Burgh are all now known to support 100,000 waterbirds and 280,000 have been recorded at one, following surveys in 2001/2002 (R.Jaensch pers. comm.).

8.4 Abundance and Breeding Activity

Survey Results

Detailed information on waterbird abundance was obtained for a range of wetlands during the survey. Of these, only five sites held greater than 1000 waterbirds. Two other sites with similarly large numbers were identified from other data. These sites were the Alice Springs Sewage Ponds (numerous surveys) and a group of lakes in the Karinga Creek Saline System, which were surveyed by Mike Fleming (PWCNT) in September 1989 (unpublished data).

The location in the southern arid NT with the highest waterbird numbers during the survey was the Lake Mackay system (table 15). A total of 40,334 birds of at least 21 species was recorded during a two hour aerial survey on 6 September 2001. Additional species were recorded during a ground survey. The most abundant species during the aerial survey were Banded Stilt (12,070), black-winged stilt (3,262), grey teal (4,653), unidentified ducks (8,460) and white-winged/whiskered terns (4,602). The aerial survey did not cover all of Lake Mackay and its surrounds, and it occurred several months after the waters had started to recede. As a consequence, it is likely that the count greatly underestimated both the number of waterbirds present at Lake Mackay and the amount of breeding that took place (Ray Chatto *in litt.*). In general, waterbirds begin to breed soon after heavy rains and, for island nesting species, often before peak water levels are reached. Therefore, a significant number of birds may have dispersed, if counts are carried out several months after maximum water levels have passed.

Lake Lewis and the Karinga Creek Saline System are two other wetlands known to hold over 10,000 waterbirds. Of the 13,000 birds counted at Lake Lewis during an aerial survey in September 2001, the majority were grey teal (12,000) with 1000 black-winged stilt also present. Six lakes in the Karinga Creek system counted by Mike Fleming (PWCNT) in September 1989 held almost 11,000 waterbirds (table 15). Calatta Spring Lake contained over two-thirds of the total number. The most abundant species were Red-capped Plover (2,341), Banded Stilt (2,351) and Sharp-tailed Sandpiper (1,955).

The Snake Creek Floodout System (36 species, 3,384 individuals) and Lake Surprise (15 species, 3,417 individuals) were other important wetlands in context of the southern arid NT (table 15).

Breeding Records

Limited breeding information was obtained during the bird surveys carried out as part of this survey as a consequence of limited search effort. It is highly probable that the bulk of the survey work was carried out after the peak breeding period. In total, evidence of breeding, either in the form of courtship behaviour, or the presence of nests, chicks or immature birds, was obtained for 15 species of waterbirds. This total included ducks and swans (Grey Teal, Hardhead, Pink-eared Duck, Black Swan), shorebirds (Banded Stilt, Black-winged Stilt, Red-necked Stilt, Red-kneed Dotterel, Red-capped Plover), cormorants (Pied Cormorant, Little Black Cormorant), Darter, Australasian Grebe, Eurasian Coot, and Gull-billed Tern. An additional 31 waterbird species are expected to breed in the study area.

The major breeding event recorded was of Banded Stilts at Lake Mackay. A total of 4,400 young were counted during the aerial survey in September 2001. As mentioned previously, it is likely that waterbirds had been breeding at Lake Mackay for several months prior to the survey taking place; therefore, breeding activity was underestimated. However, notwithstanding this possibility, the number recorded is still significant for this species especially considering the high predation rates recorded at more southerly breeding locations (Williams 1998a).

Comparison of Waterbird Abundance with Other Arid Zone Locations

Kingsford and Halse (1998) listed 22 sites in arid Australia with maximum counts of more than 50,000 waterbirds. Details of some of these sites are given in table 15. Eleven additional arid Australian sites with waterbird counts of between 10,000 and 51,000 are given in Kingsford (1995). The 33 sites with more than 10,000 waterbirds, listed by the two publications, present a baseline against which southern arid NT sites can be assessed.

Three wetland sites in the southern NT contained sufficient waterbirds to warrant being considered as being of national significance for waterbirds (i.e. >10,000 individuals). These sites are Lake Mackay, Lake Lewis and the Karinga Creek Saline System. The Lake Mackay system in particular is likely to be

of great significance nationally. It held over 40,000 birds despite being only partially surveyed well after the expected period of peak numbers. Lake Mackay appears to be a significant breeding site for the Banded Stilt. At least 4,400 young were present during an aerial survey in September 2001, a total that is indicative of a very large breeding population. The site may be as significant as other well known Banded Stilt locations such as Lake Eyre, which held 18 000 pairs in July 2000 (Wilson 2001). Although infrequent, breeding events of Banded Stilt at Lake Mackay are of great importance. There is evidence indicating that predation by Silver Gulls is much lower at Lake Mackay than at other known breeding sites, with only low numbers of Silver Gulls recorded. Silver Gulls exert intense predation on eggs and chicks of Banded Stilts (Wilson 2001) and have established large, yet highly mobile colonies close to towns, where dumps provide a continuous food source.

8.5 Conservation Status

Among the wetland birds present in the study area, 32 species are listed under international treaties. Twenty-nine (29) species are listed as part of the treaty between Australia and Japan (JAMBA: Japan-Australia Migratory Birds Agreement) and 30 species are listed as part of the treaty between Australia and China (CAMBA: China-Australia Migratory Birds Agreement). Twenty-seven (27) species are common to both agreements. However, the majority of the listed species are only vagrants to the arid NT. The non-vagrant species listed under international treaties are:

- Great Egret;
- Glossy Ibis;
- Marsh Sandpiper;
- Common Greenshank;
- Wood Sandpiper;
- Common Sandpiper;
- Sharp-tailed Sandpiper;
- Oriental Plover; and
- Caspian Tern.

Two species are listed as threatened in the Northern Territory: the Freckled Duck (sporadic occurrence in arid NT); and Painted Snipe (vagrant). Both are considered to be vulnerable to regional extinction (table 16). None of the wetland species that occur in the southern Northern Territory is listed nationally as threatened. The Australian Shelduck has not been sighted in the arid NT since 1923 (Whitlock 1924); however, it may have only ever been an intermittent visitor, and may still occur sporadically but unrecorded. The species is still recorded in the Lake Eyre basin (Kingsford & Porter 1993; R.Jaensch pers. comm.).

There is some indication that the Banded Stilt could be in decline. There are few data on population numbers of this enigmatic species that is endemic Australian and predominantly breeds in the arid zone. However, there is good evidence of increased numbers of Silver Gulls and predation by these on nestling Banded Stilts (Wilson 2001).

Table 16. Wetland birds from the arid NT that are listed under international treaties and/or as threatened species. Abbreviations are JAMBA: Japan-Australia Migratory Birds Agreement; CAMBA: China-Australia Migratory Birds Agreement; TPWCA: Northern Territory Parks and Wildlife Conservation Act; EPBCA: Environment Protection and Biodiversity Conservation Act.

Species (Vagrancy indicated in brackets)	JAMBA	CAMBA	NT Status (TPWCA)
Freckled Duck			vulnerable
Garganey (v)	✓	✓	
Great Egret	✓	✓	
Cattle Egret (v)	✓	✓	
Glossy Ibis		✓	

Swinhoe's Snipe (v)	✓	✓	
Black-tailed Godwit (v)	✓	✓	
Bar-tailed Godwit (v)	✓	✓	
Little Curlew	✓	✓	
Whimbrel (v)	✓	✓	
Marsh Sandpiper	✓	✓	
Common Greenshank	✓	✓	
Wood Sandpiper	✓	✓	
Common Sandpiper	✓	✓	
Grey-tailed Tattler (v)	✓	✓	
Ruddy Turnstone (v)	✓	✓	
Great Knot (v)	✓	✓	
Red-necked Stint	✓	✓	
Long-toed Stint (v)	✓	✓	
Pectoral Sandpiper (v)	✓		
Sharp-tailed Sandpiper	✓	✓	
Curlew Sandpiper	✓	✓	
Broad-billed Sandpiper (v)	✓	✓	
Ruff (v)	✓	✓	
Red-necked Phalarope (v)	✓	✓	
Painted Snipe (v)	✓	✓	Vulnerable
Pacific Golden Plover (v)	✓	✓	
Grey Plover (v)	✓	✓	
Greater Sand Plover (v)	✓	✓	
Oriental Plover	✓		
Caspian Tern		✓	
White-winged Black Tern	✓	✓	
Grey Wagtail (v)		✓	

Species names in bold are those which are not considered vagrant in the arid NT.

8.6 Bird Distribution Across Wetland Types

Of the wetland types listed in Chapter 8, those that held the greatest numbers of birds were salt lakes (Lake Mackay, Karinga Creek system, Lake Lewis) and freshwater lakes (Snake Creek floodout). Of secondary importance were a range of other wetland types particularly wooded swamps, and waterholes in major wooded water courses. The relative importance of these wetland types varies with the amount of inundation. Permanent and semi-permanent waterholes/rockholes in the ranges, such as Glen Helen Waterhole in the West MacDonnell Ranges, are particularly important in the regional context as drought refuges. Another major wetland in the southern arid NT is the Alice Springs Sewage Ponds. This site contains water throughout the year and supports a complete community of wetland birds, including small passerines and crakes in swampy vegetation, waterfowl in the deeper water ponds, and shorebirds in shallow water along the edge of ponds. During periods of prolonged drought, the site is an important refuge area. For example, during a drought in November and December 1978, Greg Roberts (unpublished data) counted between 2,500 and 3,000 waterbirds of 49 species.

Some wetland birds have specific habitat requirements that must be met before breeding can occur and, therefore, these species are dependent on particular types of wetlands. The Banded Stilt only breeds on salt lakes after these have been filled by rain. Crakes, rails, and small passerines (Clamorous Reed Warbler, Golden-headed Cisticola, Little Grassbird) breed amongst inundated dense vegetation that provides nest sites and protection from some predators. Other birds, including Australian Wood Duck, Pacific Black Duck and Grey Teal, use tree hollows as nests.

8.7 Significant Wetlands for Birds

The methodology of the current study was not sufficient to provide a detailed assessment of the importance to waterbirds of all wetlands in the southern NT including some of suspected importance. However, a number of sites stand out as being important based on the species richness, overall abundance and presence of significant species.

Lake Mackay held the largest number of waterbirds of any single wetland or aggregation surveyed and supports a high diversity of waterbirds, in particular large numbers of Banded Stilt. The site is likely to be an occasional major breeding location for the Banded Stilt. A population of at least 12,000 Banded Stilt was present at Lake Mackay during an aerial survey. Given that the population of this endemic species is estimated at only about 206,000 (Marchant & Higgins 1993), Lake Mackay is clearly a nationally significant site for the conservation of the species. Its significance for the species is enhanced by the absence of large colonies of Silver Gulls which are a significant predator of Banded Stilt hatchlings. Lake Mackay also supports large numbers of ducks and terns. Although the lake only episodically provides large areas of waterbird habitat, it is of international significance, meeting the criteria set up under the Ramsar Convention as discussed in the detailed account of this wetland in Volume 2.

Lake Lewis supports a large number and moderate diversity of waterbirds. Important as a site for Grey Teal (12,000 counted), when full it may support sufficient numbers of birds to qualify as internationally important, but current data do not confirm this.

Karinga Creek Saline System supports a large number and moderate diversity of waterbirds. A particularly important site for shorebirds including both migratory and resident species, it is listed in *A Directory of Important Wetlands in Australia* (Environment Australia 2001). The collection of wetlands in this system may sometimes support sufficient numbers of birds to qualify as internationally important (20,000), but current data do not confirm this.

Snake Creek Floodout System supports a high diversity and moderate numbers of waterbirds. Counts of numbers are likely to be far lower than maximum since not all the lakes were surveyed and 20 months had passed since initial inundation.

Lake Surprise (Yinapaka) supports a moderate diversity and abundance of waterbirds. It is listed in *A Directory of Important Wetlands in Australia* (Environment Australia 2001). Counts of numbers are likely to be far lower than maximum since the lake was surveyed well after the initial inundation.

Alice Springs Sewage Ponds, over a yearly cycle, supports a very high diversity of waterbirds (up to 50 species). In the summer of 2000-2001 and 2001-2002, between 1,500 and 2,000 waterbirds from 29 species were usually present at this site. In winter 2001 and 2002, between 750 and 1,000 individuals of 21 species were observed. The waterbirds recorded at this site include species threatened in the NT (Freckled Duck, Painted Snipe) and a large number of species listed under CAMBA and JAMBA (tables 3 and 4). The Alice Springs Sewage Ponds are an important drought refuge and an internationally-known location for observing Australian waterbirds. The location is an important educational resource. A good case for the international importance of this site can also be made against the criteria for international significance set up under the Ramsar Convention, as discussed in the detailed account of this wetland in Volume 2.

8.8 Arid NT Wetlands Birds: National Perspective

The NT wetlands strategy (PWCNT 2000, p.5) states that a 'recent estimate of the number of waterbirds using wetlands in the arid and semi-arid zones over the whole of Australia has put the figure at around 8 million. Our limited knowledge of these systems precludes any estimates of how dependent these large waterbird populations are on the arid-zone wetlands of the Northern Territory.'

Although most of the arid NT wetlands that support medium to large bird populations only provide episodic bird habitat, they may still play a vital role in maintaining national species populations. Some swamps fill relatively frequently, once or twice a decade, whilst others may only fill a few times in a century, such as the large salt lakes of the Karinga Creek system and the vast expanses of Lake Mackay, Lake Amadeus, and Lake Lewis among others. Some species of wetland bird commonly live for over a

decade (e.g. Variable Oystercatcher >19 years, masked lapwing >11 years). Even though several generations may pass between major inundations of the large salt lakes, these habitats may be important as part of a national collection of habitats that support breeding. For example, the Banded Stilt only breeds during episodic filling of salt lakes in central, western and southern Australia. As a consequence, breeding of the species is an unpredictable event that occurs spasmodically and, when it does, successful rearing of young is imperative for the continued survival of the species. Therefore, it is essential that all major breeding sites of such a species be managed to reduce disturbance and to ensure successful reproduction when breeding events do occur. Salt lakes in the southern NT, especially Lake Mackay, should play a major role in future conservation.



9. Wetland Plants in the Arid NT

Scope

Many wetlands may be dry when surveyed, and it may not be readily apparent that an area is a wetland or where its boundaries are. A good knowledge of the affinities of plants to various wetland habitats can be central in determining the wetland type of a particular wetland or even in determining if an area is a wetland. Developing the use of plant species to identify wetlands and describe their character has been a core element of this inventory.

Perennial plants are the most persistent element of the biota of temporary wetlands and consequently are the most consistently measurable element of the biota. Non-perennial plants may not always be visibly present when a wetland is visited. However, following inundation, non-perennials have an important role in defining the ecological character of some wetlands.

Greater survey effort was expended on plants than on the various animal groups in the field survey, for the following reasons:

- vegetation is often a key attribute in wetland classification and description;
- vegetation can be a key indicator that a dry area is a temporary wetland;
- vegetation is the longest lasting biological attribute of temporary wetlands and therefore can be more consistently surveyed than fauna;
- vegetation provides habitat for various wetland fauna;
- knowledge of the conservation status of plants is sufficiently advanced that some wetland species have rare or threatened status such that their presence is a basis for declaring a wetland as significant;
- many such plant species are small and hard to detect without systematic survey;
- several wetland plants have been assigned a conservation status of 'poorly known' (equivalent to 'data deficient') and systematic survey provided a basis for reevaluation of their status; and
- expertise within the Parks and Wildlife was sufficient to identify species and manage the resulting data through the NT Herbarium.

Goals for vegetation survey during the inventory were to:

- determine characteristic and important species for classification (determining and describing wetland types);
- record characteristics of specific important wetlands;
- add to species distribution knowledge;
- add to knowledge of the habitat preferences of wetland plants; and
- contribute to the NT Herbarium specimen collection.

In this chapter we report on the survey methods used for vegetation and soils, some preliminary results and an outline of planned future analysis. Various ways of classifying wetland plants are considered and an overview presented of characteristic species and groups of species in the arid NT.

Scientific and common names follow the digital checklist based on the *Vascular plant checklist for the southern bioregions of the Northern Territory* (Albrecht *et al.* 1997 and Albrecht *et al.* 1999).

9.1 Methods

Sampling Strategy Within Wetlands

Vegetation was systematically surveyed at a subset of the survey sites. The method used was flexible to be compatible with the overall survey goal of surveying a large number of sites. In order to meet the goals, we aimed to obtain full or representative species lists for whole wetlands and sub-habitats within wetlands. Where time permitted, cover and abundance were recorded using a modified Braun-Blanquet system, as presented in the survey proforma appended to this report. At some sites there was only time for recording dominant and characteristic species. At other sites a full species list was ascertained but without cover-abundance data and not subdivided by sub-habitat. At some large and complex wetlands, a full species list with cover abundance estimates was obtained for various sub-habitats.

Sub-habitats are defined here as zones or patches within a wetland with relatively uniform vegetation and substrate. In some instances sub-habitats corresponded to the different wetland types in the preliminary classification. The spatial patterning of sub-habitats may occur at various scales from patches of a few metres to patches of hundreds of square metres, and the survey method needed to account for this range of scales. The first step in sampling the sub-habitats was to subjectively identify them and write a brief description of their distinguishing features, including dominant species, topographic position, surface soil or rock type and presence of water. In most cases, a sketch map was drawn indicating the patterning of sub-habitats and the surrounding landscape of the wetland.

The size of sampling areas (quadrats) was not standardised. This allowed maximum flexibility in obtaining comprehensive species lists in the least amount of time. Systematic but representative sampling of sub-habitats would have required much more time than was available (e.g. several small fixed area plots in each zone and/or a gradient-transect method).

Vegetation sampling quadrats were positioned subjectively within subhabitats with the aim of recording data that were representative of the sub-habitat. Randomising the position would not have provided any advantage in this type of survey. At some smaller wetlands, the entire area of a particular sub-habitat patch was searched, or the entire extent of a sub-habitat searched. Many sub-habitats were bands that fringed the deepest part of the wetland, such as river banks and the shores of lakes. Where these were only a few metres wide they were observed by simply walking along the sub-habitat and the quadrat approximated a linear transect.

Some effort was expended to incorporate a draft Parks and Wildlife protocol for vegetation survey into the methods for this inventory. However, the draft Parks and Wildlife protocol included attributes that were not required for the wetland inventory and was based on fixed size quadrats of 30 m by 30 m or equivalent. For the wetlands survey a more flexible approach was required to maximise the amount of useful information that could be collected in a short time and from a wide variety of spatial patterns of habitat. Often an area of 30 by 30 m was too small to encompass the apparent variation within a sub-habitat, and in other cases, a 30 by 30 m quadrat incorporated several sub-habitats.

Vegetation structure was briefly described in terms of dominant species, estimated cover and height. At a subset of vegetation survey sites the vegetation structure and condition were recorded using the draft Parks and Wildlife protocols for vegetation survey. This was typically where the layout of the site was compatible with a rectangular plot equivalent to a 30 by 30 metre square.

A more formal method for surveying the variation within wetlands is described by Blackman *et al.* (1992). It includes a standard method for sampling various zones within a wetland, along a transect that intersects the zones. In their terminology a zone or sub-habitat is a 'segment' and the main transect is a 'gradsect'. In a reconnaissance level inventory, such as this one for the arid NT, their detailed method was too time consuming, as it did not allow the correct emphasis on sampling large numbers of wetlands.

Personnel and Species Identifications

A member of the survey team who specialised in botanical survey was available for most field trips (David Albrecht, Jenni Risler or Peter Latz). The unavailability of an experienced botanist for four survey trips meant that staff with general botanical skills conducted the vegetation assessments (principally Angus Duguid but also Jason Barnetson). Their expertise was sufficient to recognise distinct

species in the field and estimate cover and abundance classes, but it was necessary to collect a great many pressed and dried specimens for subsequent identification in the Herbarium (Alice Springs Desert Park). The floristic vegetation data sheets included a column for recording the initials of the person identifying the species.

Soils

For most of the sites where detailed vegetation survey was undertaken, one or more soil pits were dug. The standard depth was 300 mm, but where subsurface clay was expected, further depths were explored. In some cases shallower pits were dug to sample the top 10cm only, such as on the steep banks of watercourses and when there was insufficient time for more thorough sampling. At many sites, each individual sub-habitat was sampled with a separate soil pit.

Where soil pits were dug, the profiles were described including: horizonation, stoniness, presence of calcareous nodules and mottling. A sample was taken from each horizon when distinct horizons were observed. When distinct horizons were not observed, samples were taken at depth ranges of 50-100mm and 250-300mm. The nature and thickness of surface soil cracking was noted.

Texture, presence of carbonates, pH and abundance of coarse fragments were determined from soil samples using the methods described by McDonald *et al* (1990). Soil colour was recorded by comparing soils with colour charts, using the Munsell Colour system. Where time permitted these observations were made in the field; otherwise, they were made in the laboratory from the sample.

Soil conductivity was measured for all samples in the laboratory, as an indicator of salinity. A 1:5 mixture by weight of soil to water was prepared. A precision balance was used to weigh 8g of the aired dry soil, to which 40ml of demineralised water was added, in a small sample jar. The solution was vigorously shaken by hand for 1 minute and the conductivity measured using a TDScan 10/20-conductivity meter and recorded in micro semens ($\mu\text{S}/\text{cm}$). This method was deemed sufficient to indicate general levels of salinity in soils, following advice from soil scientists from the NT Government Natural Resource Assessment Branch (A. Kennedy pers. comm.).

A description including estimated surface soil texture was completed when time did not permit digging a soil pit. Where the wetland was mostly under water, some attempt was made to estimate the nature and/or soil texture of the inundated soil.

9.2 Preliminary Results

Wetland Plant Sub-habitats

Here we present some preliminary observations on the main habitats for wetland plants in the arid NT, referred to in this report as sub-habitats. These are based on observations at survey sites for the wetland inventory. In some cases, sub-habitats correspond to wetland types, but in general, they are at a finer scale and are components within a wetland type. Some of the common sub-habitats are listed below. This is a preliminary and incomplete list, and those sub-habitats that correspond to wetland types are generally not listed below, for example 'bluebush swamp'.

It is hoped that a more detailed account of this subject will be prepared following numerical analysis of the survey data, resulting in descriptions of the various small scale vegetation communities that make up arid NT wetlands.

Open water – fresh and saline – various floating and submerged aquatic plants occur.

Riverine – broad sandy river beds – generally very sparsely vegetated.

Riverine sandy islands with *Eucalyptus camaldulensis*.

Riverine waterholes with rocky substrate and banks.

Riverine waterholes with sandy substrate and banks.

Riverine waterholes with loam or clay substrates and banks.

Moist banks – loam or clay banks of watercourses and waterholes and typically with steep gradient.

Herbaceous herb banks – typically shallow loamy/clay banks of waterholes in north east.

Upper river banks – dominated by *Eucalyptus* species.

Fringing reed beds – *Phragmites australis*.

Fringing Bullrushes (*Typha domingensis*).

Moist fringes of wooded swamps – includes a rich mixture of herbaceous plants including sedges.

Moist edges of inundated bare claypans – various mat forming plants typically occur.

Fringing Coolabah woodland of unwooded swamps and claypans.

Upland fern beds associated with springs.

Upland fern walls – small ledges or cracks in steep sheltered rock walls, with seepage and ferns.

Damp shady upland creeks – support *Callistemon pauciflorus* for example.

Heavy clay pans – typically bare.

Lighter soil pans (sandy clays, clay loams, sand overlying clay) – relatively vegetated.

Stony clay pans.

Gilgais.

Riverine grassy swamps – adjacent to drainage lines or minor floodouts - typically dominated by *Eriachne* species, including *E. benthamii s.lat.*, but also *Imperata cylindrica*.

Sandy fringes of salt lakes – typically with a mix of species including grasses, notably *Eragrostis falcata* and sub-shrubs, such as *Lawrencia glomerata*, *Maireana luehmannii*, *Sclerostegia tenuis* and also *Halosarcia spp.* (Samphire).

Samphire fringes – typically on the edges of salt lakes, subject to inundation and dominated by *Halosarcia spp.*

Preserved Specimens

A huge amount of data was collected for wetland plant species, adding to both distributional and ecological knowledge. Confirmed species records were obtained for 321 sites, including 376 records of threatened, rare or poorly known (data deficient) taxa (269 taxa). Over 800 voucher specimens will be lodged with the NT Herbarium, providing a resource for taxonomic research. A preliminary list of wetland plants has been produced. Valuable distribution data for various weed species was recorded.

New Data for Assessing Conservation Significance

A great many new plant species records have been collected during the inventory. The data will allow the conservation status to be revised for some species. The survey data are also a basis for better descriptions of habitat preferences and threatening processes. A few examples are presented here.

Eleocharis papillosa was listed as nationally rare (R) by White *et al.* (2000a), however it was subsequently reassessed and listed under NT legislation as nationally vulnerable (V). Despite surveying several hundred wetlands for plants, following two years of exceptional rain, only one new location was recorded near Lake Mackay. This confirms its rarity. Searching at Illparpa Swamp could not relocate it and the area where it had previously been found was heavily infested with *Cynodon dactylon*. It was recollected at Stirling Swamp, but *Cynodon dactylon* is actively spreading there also. There is a reasonable case for revising its status to Endangered.

Isotoma luticola is listed as nationally rare (R) by White *et al.* (2000a). It is highly restricted to temporary swamps, but was abundant at several sites surveyed.

Several wetland plants were classified as ‘poorly known’ (data deficient) by White *et al.* (2000a). As a result of the inventory the conservation status of some can be revised. Examples include *Mimulus prostratus* (21 sites) and *Stemodia A57025 Manners Creek* (8 sites including a range extension of 200 km).

9.3 Ecological Attributes of Arid NT Plants

Various ways of classifying wetland plants are explored here as a framework for discussing their general ecology. This draws on observations of the authors including the ground survey component of the inventory, NT Herbarium records and published literature.

Definition of a Wetland Plant

Wetland plants are broadly defined here as plants species that occur more frequently in wetland environments than outside of them because of a requirement for abundant water at some point in their lifecycle. Since many wetlands of the arid NT are temporary it follows that many of the plants that live in them can tolerate long dry periods. Our definition includes all species that have some competitive advantage in, or adaptation to, periodic inundation. This does not mean that all wetland plants can thrive or survive prolonged inundation by water. Many species are killed by prolonged waterlogging or submersion but establish a new generation from seeds or spores during or immediately following inundation. It is not always known which environmental parameters are controlling species distributions. Some species are adapted to physical parameters other than abundant free water but which most often occur in wetlands, for example, saline soils. Thus, some of the species that typically grow on the margins of salt lakes may not have a requirement for abundant water, but nevertheless have a strong fidelity to saline wetlands.

It is also common to find non-wetland plants in wetlands. These are plants that occur widely across the landscape, including in wetlands. In some instances, such plants may establish in wetlands between inundation events but are killed at the next major inundation. Some non-wetland plants are able to survive limited periods of inundation but are nevertheless widespread outside of wetlands.

Our broad definition is in contrast to terms often used for plants in more persistently wet wetlands, such as 'aquatic plant', 'aquatic macrophyte' and 'hydrophyte'. Definitions for these terms and their applicability are discussed below. Most incorporate a stronger relationship with the presence of free surface water than our broad definition.

Pajmans *et al.* (1985) use a definition of temporary wetlands in which the occurrence of waterbirds or 'hydrophytic plants' is an essential criteria. The term 'hydrophyte' is given several definitions by Lincoln *et al.* (1998):

Hydrophyte:

1. Perennial plant with renewal buds below the water and submerged or floating leaves.
2. Any plant adapted to live in water or very wet conditions;
3. A plant requiring a large amount of water for optimum growth.

The third of these definitions comes closest to our broad definition of a wetland plant and could be adapted to further define a '**wetland plant**' in the arid NT as:

plant species that occur more frequently in wetland environments than outside of them, typically because relatively large amounts of water are required for optimum growth, at some stage in their life-cycle.

Fidelity of Wetland Plant Species to Wetlands

Our definition of a wetland plant is based on fidelity of species to wetlands. Those that are more often found in wetlands than in drylands are considered as having fidelity to wetlands. We have developed a coding system for fidelity and have used it to rate some of the arid NT wetland species. The resulting list of arid NT wetland plants is still in a preliminary state.

It is intended to rate species their fidelity with a numerical code of 1 (low fidelity) to 5 (high fidelity) but this task is incomplete. Those coded as 5 are rarely found outside of wetlands and include all aquatic and semi-aquatic plants. Species coded as 1 are often found outside of wetlands but are more likely to be found in wetlands. Plants that frequently occur in wetlands but with no clear fidelity were coded with a question mark '?', indicating that they may qualify for a code of 1 or higher but there was insufficient information to make that decision. Species that require or tolerate temporary waterlogging rather than inundation may have low fidelity, because waterlogged soil occurs at very small scales, scattered

throughout the landscape. Those that require long-term waterlogging have very high fidelity (5) to wetlands, even though they may be rarely inundated.

The assessment of fidelity was somewhat subjective but took into account survey data and Herbarium specimen label information as well as the general observations of the authors.

It is important to note that some species that have a wide distribution across the study area have a higher fidelity to wetlands in the more arid, southern part of the study area and a lower fidelity to the north, where the rainfall is higher and more predictable.

Plant Responses to Abundant Water

Most studies of plants in wetlands have been based in less arid regions than the arid NT, and many are focused on plants that predominantly grow in water. Our definition of wetland plants is much broader; however, the degree to which species live in or rely on surface water is still an important aspect of arid zone wetland plants. Surface water is water standing or running above the ground, during inundation. Those plants which are most reliant on surface water are loosely referred to as aquatics or aquatic macrophytes. Species that do not require inundation and have only limited tolerance of inundation are broadly grouped as 'dryland' (also termed 'non-aquatic' and 'terrestrial'), while species with intermediate requirements for and tolerance of free water are usually called 'semi-aquatic' or 'amphibious' (Aston 1977).

Brock (1994) provides an excellent introduction to the physical and characteristic attributes of aquatic environments as a medium for plant growth.

Definitions of Aquatic and Semi-aquatic Plants

There is no universally recognised definition for aquatic plants (Aston 1977). Lincoln *et al.* (1998) define aquatic simply as:

'living in or near water; used of plants adapted for a partially or completely submerged life.'

Williams defines macrophytes in *Life in Inland Waters* (1983) to include some algae, moss and liverworts, as well as vascular plants, that have their:

'principal food making structures submerged in, emergent from or floating upon bodies of inland water'.

Aston (1977, p.1-2) provides a more detailed definition of aquatic plants and discusses the often imprecise distinction between aquatics and semi-aquatics. Her definition is as follows.

'aquatic species are considered to be those adapted to growing in or on permanent water, either completely submerged or emergent, and having a definite life form (habit, structure) related to this aquatic environment. They are entirely dependent on the presence of permanent water for the survival of the individual plants, and can never be found far from it. When water levels recede, some aquatics may survive on the damp or saturated strand areas either by assuming a suitably modified life form which differs considerably from that shown by the same species when growing in water, or by means of resistant root systems which may allow survival for some months, but generally with a deterioration in the general vigour of the individual plants. With severe and prolonged dryness death occurs. Essentially, existence on damp land may be regarded as a survival mechanism only, and the main life form of the plant is adapted to a permanent aquatic environment. In contrast, terrestrial species are considered to be those which normally occur on damp or near-dry land, and which will survive for only a short time if inundated. They cannot live in permanent water. Between these extremes, environment involving alternate periods of inundation and of partial dryness, their life form remaining essentially unaltered throughout. Hence they are typically found bordering areas of permanent water, in bogs and shallow swamps, and in areas subject to only shallow, seasonal inundation. It is not always possible to decide if a species should be regarded as a true aquatic or as a semi-aquatic'.

A notable feature of Aston's (1977) definition of aquatic plants is the dependence on permanent water. In the arid NT 'permanent' must be replaced by 'long-lasting' for the definition to be meaningful. There are several arid NT plant species which complete all or virtually all of their life-cycle in free water that is not permanent; for example *Ruppia maritima* which only grows in surface water and can become abundant in temporary inundations in salt lakes. There are some species which predominantly grow in very long-term

to semi-permanent water but possibly none that are totally restricted to permanent waterbodies. The aquatic grass, *Phragmites australis*, is one of the species that is most reliant on permanent water, occurring mostly on the fringes of permanent waterholes plus at a few semi-permanent wetlands. Some essentially aquatic species are often found in isolated artificial water bodies, probably due to dispersal by birds, e.g. *Potamogeton spp.*

It is difficult to define semi-aquatic other than as intermediate between aquatic and non-aquatic. Boulton and Brock (1999, p.68) equate amphibious plants with semi-aquatic: '[amphibious plants] are considered semi-aquatics as they live on the margins of wetlands and can be subjected to periods of inundation or drying out'. Brock and Casanova (1997, p.184) define amphibious species as those 'that either tolerate or respond to the presence or absence of water'. The predominance of temporary wetlands in the arid NT means that most wetlands typically dry out completely between filling events. Accordingly, many semi-aquatic plants grow in the beds of drying out wetlands, not just on the margins. Typically these plants will establish and grow in water, following flooding, and continue to grow for some time after surface water has disappeared. Typically, they will then die when conditions become too dry, but occasionally, a subsequent flooding event will occur resulting in a return to an aquatic state.

It may be useful to distinguish those species that can survive without surface water but nevertheless require saturated soil from those that can also tolerate drying out of the surface soil. It may also be useful to distinguish species that require inundation to establish or reproduce from those that can complete their entire lifecycle without inundation, yet may also thrive in conditions of prolonged inundation. The former could be described as 'semi-aquatic' and the latter as 'amphibious', rather than the usage that treats the two terms as synonymous (e.g. Boulton and Brock 1999; Aston 1977). A possible example that meets this definition of 'amphibious' is *Isoetes muelleri* which may only require moist soil to germinate and reproduce. Due to lack of sufficient information about the requirements of individual species, this distinction is not adopted here for arid NT plants.

The following definitions for aquatic and semi-aquatic are adopted here.

Aquatic - grows predominantly in surface water and able to complete its lifecycle in water but may also tolerate limited periods without surface water and may persist in the seed bank of temporary wetlands. Those that quickly deteriorate if water dries up may be regarded as 'strictly aquatic', whilst those with mechanisms that sustain growth for longer dry periods can be regarded as 'generally aquatic'.

Semi-aquatic - mature plants can thrive for extended periods in surface water but can also thrive in drier conditions. Most semi-aquatic species require inundation at some stage of the lifecycle, typically for germination. Plants may be able to reproduce in water. Species that typically produce seeds or spores following drying (post-inundation) out are also included.

Categories of Response to Abundant Water

Many species that are not aquatic are nevertheless adapted to the inundation regimes of temporary wetlands. Adaptations may be in the form of an active morphological or life cycle response to the amount of water present or may be a tolerance of inundation (Brock & Casanova 1997). Similarly, species have various preferences for or responses to waterlogged (saturated) soils.

The life cycle responses to inundation may be classified according to the degree to which species rely on abundant water to germinate, establish and reproduce. Brock and Casanova (1997) identified functional groups based on numerical analysis of survey data from two temporary shallow wetlands on the Northern Tablelands of NSW. Although their study sites were relatively frequently inundated compared to many arid NT wetlands, they contained some of the same species as found in the arid NT, and the analysis is highly relevant to the arid NT situation. Several categories of response to temporary water regimes are listed below and are variously influenced by those of Brock and Casanova (1997).

Establishment for many arid wetland species occurs at the edge of receding water bodies, such as claypans and swamps and these were collectively referred to by Pajmans *et al.* (1985, p.37) as 'herbaceous shore plants'. Inundation probably triggers germination in most of these species, but the actual germination and early establishment of vegetative parts (shoots and leaves) is post-inundation in saturated soil. Wetland species may be grouped according to both the conditions which trigger germination and the amount of water present during actual germination and establishment.

Germination may be triggered by:

- persistent inundation (lasting weeks to months);
- persistently saturated soil (lasting weeks to months); or
- damp soil.

Germination and establishment may occur:

- under water;
- in saturated soil; or
- in damp to dry soil.

Turbidity and depth are also important influences on germination and establishment. Many species will not establish in relatively deep water. In our survey, germinants of *Marsilea sp.* were kicked off the bottom of water up to 1 metre deep, while wading. Germination may have occurred at greater depths; however, we did not sample plants below 1 m depth. *Typha domingensis* does not occur in highly turbid waters such as claypans, where little light penetrates to the substrate. For most species, germination requirements can only be inferred from where they are observed establishing, their topographic position in the wetland and associated inundation regime. Species that only require brief saturation to germinate may do so in response to rainfall, even when runoff is insufficient to substantially inundate a wetland. Such species are likely to also occur outside of wetlands unless other adaptations, such as tolerance of inundation, give them an advantage in wetlands.

The abundance of water that is required for reproduction, or the amount of water that is typically present at reproductive maturity may be useful in classifying plant responses to temporary inundation. Reproductive maturity is defined here as production of seeds or spores. Brock and Casanova (1997) differentiated two categories of surface water depth and two categories of soil moisture for when plants reproduce:

- shallow water (< 10 cm);
- deeper water (>10 cm);
- saturated soil;
- dry soil.

Some species produce seeds or spores in response to drying out, yet they not only establish under water, but also thrive for substantial periods in an aquatic state. Nardoo (*Marsilea spp.*) produce spores in storage tissues at the base of the stems, called sporocarps. In our survey these were only ever found in dry soil and not on plants that were in saturated soil or growing in water.

The amount of water present when plants do most of their growing may also be used to classify species as either:

- submerged in surface water;
- emergent from surface water;
- growing in saturated soil; or
- growing in damp to dry surface soil.

Some perennial wetland species appear to be favoured by reliable and long-term water availability but do not necessarily require saturated soil or inundation. This group includes woody perennials that predominantly grow on the edges of long-term waterholes in drainage lines and some of the relictual fern species that require mesic conditions.

Categories of Tolerance of Abundant Water

Adaptations to temporary water regimes may also be in the form of tolerance (survival) of inundation, rather than active responses to it. Adult plants of some non-aquatic wetland species are relatively tolerant of inundation, giving them a competitive advantage in wetlands, relative to those species which are more

readily killed by inundation. Similarly, some species have various tolerances of waterlogged (saturated) soils. Many annual species germinate in response to inundation and establish at the wet edges of receding surface waters, yet are not tolerant of subsequent inundation if it occurs during their lifespan.

Many species with erect habits are able to tolerate inundation as long as part of the plant remains out of the water (emergent). These include many grasses and other graminoid taxa such as sedges and rushes. Some are perennial and some are annual. Several species of woody trees and shrubs tolerate periods of sustained inundation but not complete submersion. For example, both *Eucalyptus camaldulensis* (River Red Gum) and *Eucalyptus victrix* (Gum-barked Coolabah) tolerate inundation, but *E. victrix* typically occurs in less sandy, more loamy or clayey soils where inundation lasts much longer. Two species of shrubs are common structural dominants in wetlands and tolerate inundation, but not complete submersion, lasting many months: *Chenopodium auricomum* (Northern, Queensland or Swamp Bluebush; Bluebush) and *Muehlenbeckia florulenta* (Lignum). Several *Melaleuca* (Tea Tree) species tolerate some inundation, but presumably only shorter lasting inundation than Bluebush and Lignum since *Melaleuca spp.* are relatively rare across the beds of basins but often occur on the fringes. However, in the survey, healthy *Melaleuca glomerata* plants were observed in surface water that had been present for four to five months.

The following categories may be useful, although they are subjectively derived and not based on survey or experimental data. They are based on the depth and duration of inundation which is tolerated.

Depth of submersion tolerated:

- root zone – waterlogged soil and very shallow surface water (< 5 cm);
- stems substantially inundated, but tops are emergent;
- entire plant submerged.

Duration of inundation tolerated:

- brief (< 1 week);
- moderate (> 1 week);
- long (> 1 month).

Brock and Casanova (1997) state only species that tolerate waterlogging and submersion will survive in the deeper areas of a wetland. They also note that some species or communities can tolerate variable conditions or move in or out of zones depending on conditions. In the arid NT the length of time between inundation events can be a matter of several years or decades, complicating the situation. Long dry periods allow wetland environments to be colonised by plants which do not tolerate inundation and which generally die when inundation reoccurs.

Plants Species as Indicators of Inundation Regime

Plant species that have strong responses to, or tolerance of, inundation have strong affinities to wetlands as opposed to drylands. Distribution records of such species may be a useful tool for mapping wetland distribution and indicating the water regime of individual wetlands. Some species only occur in long-term waterholes or river systems that contain them. Some species that occur in temporary wetlands may require relatively frequent inundation. Little information about these sorts of habitat preferences is available. The information that does exist may be a useful guide to the patterns of inundation that a wetland experiences, but this requires further testing.

Storrs and Finlayson (1997) include distribution maps of some wetland species using NT Herbarium data, as an indication of wetland distribution. The scale of presentation of their maps does not allow assessment of the utility of this approach. As a result of our inventory there is substantially more information about the location and nature of wetlands and new survey records for many plant species. This will allow further exploration of the use of 'indicator plants' as surrogates for other information on inundation regime.

Growth Form and Longevity Categories for Wetland Plants

Growth form and longevity are important ways of categorising plants. Not only do they relate to vegetation structure and other aspects of ecological function, they are readily understood by non-botanists. Characteristics that are pertinent to classifying wetland plants in relation to water regime are defined here, based on definitions applied in '*An Interactive Flora of the MacDonnell Ranges Bioregion*' (Albrecht and others in prep.). In some cases there is a strong correlation between growth form and particular taxonomic groups, such as grasses.

The longevity of plants is described as '*annual*' or '*perennial*'. Annual plants are those which usually live for only one year or growing season before dying with subsequent regeneration from seed. Those that live longer are perennial and can be divided into '*short lived*' (2-3 years) and '*long-lived*'. Boutin and Keddy (1993) included life span (or longevity) in their effort to classify wetland plants into guilds. There is considerable observational information on the longevity of arid NT species but it has not been fully collated.

Woody plants are those that have woody stems or trunks and are all perennial. Trees are tall woody plants and are defined here as follows.

Trees: tall woody plants which grow to taller than 2 m; typically with one or few dominant trunks with major branches well above the base. A single species of palm is included in this group although palm stems are more pithy than woody.

A '*shrub*' is defined here as follows.

Shrubs: woody plants that are smaller than trees and mallees, generally with multiple branches from the lower stem.

Shrubs are typically smaller than trees, however various mallee eucalypts and Coolabah trees (*Eucalyptus coolabah subsp. arida* & *Eucalyptus victrix*) can form very low woodlands of only 2 – 4 metres, even when several decades old. In contrast, some Acacia species can grow as tall shrubs and sometimes as trees.

The distinction between shrubs and non-woody plants is not always straightforward. An intermediate category called '*sub-shrub*' is defined here as follows.

Sub-shrubs: semi-woody plants which are intermediate between shrubs and forbs - generally smaller than 1m tall and somewhat woody at the base but herbaceous above.

All non-woody plants are '*herbs*'; a term which includes grasses, sedges, rushes, ferns and forbs (dicotyledenous herbs). Grasses and grass like taxa such as sedges and rushes may be collectively referred to as graminoid. Some graminoids are tussock forming. Most graminoids have an erect habit, with some important exceptions among the grasses. Grasses with a creeping habit may be stoloniferous, meaning they can develop new roots along the stems.

Some grasses and forbs are very tall, over two metres, and provide considerable structure in wetland vegetation.

Another growth form that is characteristic in some wetlands is succulence. Succulent plants have stems and/or leaves that are fleshy and have very high moisture content. Some, such as *Halosarcia* species are salt tolerant and typically form low succulent shrubs which are woody towards the base. Species of *Halosarcia* can form a low shrubland known as samphire.

Some wetland plants have a characteristic and relatively dense prostrate habit, referred to as 'mat-forming'.

For aquatic and semi-aquatic plants an important aspect of growth form is the location of parts of the plant relative to the water surface. Leaves, stems and flowers may be either:

- submerged;
- floating on the surface; or
- emergent above the surface.

Aquatic and semi-aquatic plants may also be divided on whether they are rooted in the substrate or free floating. In the arid NT, all vascular plants are primarily rooted, although some may be able to survive for some time if they subsequently become detached.

Brock and Casanova (1997) grouped growth forms of photosynthetic parts into:

- low-growing (e.g. prostrate);
- upright; and
- floating.

Other Habitat Attributes for Classifying Wetland Plants

Plant species may be grouped according to other aspects of the physical environment in addition to the water regime and their response to it. The most important is the nature of the substrate. For example, some plants are typically found on sandy soils, whilst others are favoured by clay soils and others by rocky areas. The chemistry of the substrate is also an important determinant of the species that will grow and particularly the salinity. Often the combination of substrate and topographic position within the wetland are the basis for defining habitats (or 'sub-habitats' in the terminology of our survey) which have relatively uniform vegetation.

Numerical analysis from survey data may reveal objective groupings of plants that are commonly found together. Such groups may be called plant communities and are often described in terms of their dominant species. Some species have a relatively high fidelity to particular habitats and are rarely found elsewhere. Thus, for some species, the habitat or plant community provides a basis for classifying them.

The following common broad habitats were used:

- saline habitats;
- aquatic habitats;
- clay soils (typically claypans);
- reliably mesic;
- waterhole margins;
- gypseous habitats;
- other

In the preliminary list of wetland plants the fidelity of species to some common habitats has been assessed. Currently the fidelity is ranked yes, maybe or no. In the future it would be preferable to code taxa from 1 (low fidelity) to 5 (high fidelity).

Classifications Combining Water Response, Growth Form and Habitat

There are various possible purposes for classifying wetland plants. These include understanding ecological function, delineating wetland environments or types and the identification of species. Typically, a variety of aspects of plants and their environment are combined to create useful groupings. Sometime aspects of taxonomy are included such that families or groups of families are distinguished; for example grasses, rushes and sedges may be treated separately.

Sainty and Jacobs in *Waterplants in Australia* (1998) define 7 groups of growth form to assist with identification of aquatic plants:

- free floating in water;
- floating attached;
- submerged or emergent with fine or feathery leaves;
- submerged, not feathery;
- emergent with narrow leaves (non-woody);
- emergent with broad leaves (non-woody);
- trees and shrubs.

Of these categories, only one - free floating - does not occur in the arid NT.

Boulton and Brock (1999) present a functional classification of photosynthetic aquatic producers, based on the following divisions, including growth form:

- suspended and free floating vs. attached;
- microscopic vs. macroscopic;
- rooted vs. not rooted (e.g. macro algae attached to plants or sediments);
- nature of leaves (floating, submerged or emergent) and dependence on surface water.

Rooted vascular plants that can grow in aquatic environments are further subdivided by Boulton and Brock (1999) into:

- floating;
- submerged;
- emergent;
- amphibious; and
- semi-terrestrial.

Additional categories are needed to usefully group all species that fit in our broad definition of 'wetland plant'. The following broad categories (box below) are proposed as useful for arid NT plants. They incorporate growth form characters and reliance on or tolerance of free water.

Aquatic herbs - only grow in surface water, requiring inundation for most of their life-cycle. All vascular aquatics in the arid NT are primarily rooted in the substrate. Any free floating plants are likely to be filamentous algae. Aquatic herbs are grouped for identification purposes into:

- submerged (at least partially) with fine or feathery leaves
(*Myriophyllum verrucosum*, *Ruppia maritima*)
- submerged, not feathery
(e.g. *Isoetes muelleri*)
- floating leaves on water surface
(*Ottelia ovalifolia*, *Nymphaea sp.*, *Nymphoides spp.*)
- emergent aquatic graminoids
(grasses, sedges, bullrushes)

Semi-aquatic herbs - thrive in or out of surface water. They typically require free water at some point in their life cycle, but can survive for some time without free water.

Non-aquatic graminoids - includes grasses, rushes and sedges, many of which have moderately high tolerance of inundation, when they are typically emergent, but they do not thrive indefinitely in water, and so are not semi-aquatic. A few species have prostrate growth forms. Species that require highly reliable damp or saturated soil are included.

Non-aquatic forb - many of these species probably require free water to germinate, including those that germinate whilst seeds are inundated and those that germinate when the free water has gone and typically grow to maturity in saturated or damp soil on the edges of receding waters. These may eventually cover the entire floor of a temporarily inundated basin. This category also includes species that grow in temporarily inundated riverine habitats. The species have a range in tolerance to soil drying and longevity and may be annual or perennial. Species that require highly reliable damp or saturated soil are included, such as relictual ferns. Typically these species grow less than 1 metre tall and many are prostrate. A subcategory of tall growing annuals may form dense stands in some wetlands (tall non-aquatic forbs) with all species being in the pea family (Fabaceae).

Trees that tolerate sustained inundation - non-aquatic.

Shrubs that tolerate sustained inundation - non-aquatic (e.g. *Chenopodium auricomum* & *Muehlenbeckia florulenta*).

Relatively intolerant perennials - various perennial species typically grow on the fringes of wetlands and in very temporary swamps and flood prone flats. Various growth forms are included and provide a basis for further subdivision: trees, shrubs and sub-shrubs. Various wetland types may also provide a basis for subdividing this category such as claypans, waterholes of sandy rivers, waterholes of rivers in clay plains and salt lakes.

9.4 Dominant and Characteristic Plants of Arid NT Wetlands

This section consists of brief descriptions of the characteristic native plants of arid NT wetlands. The aim is to provide an overview of wetland plant species of the arid NT to assist in future inventory and study of wetland ecology.

Some plants are structural dominants that strongly influence wetland appearance. Structural dominants also influence some ecological aspects, especially providing roosting and nesting opportunities for birds. A number of woody perennials are included which are not wetland plants, being widespread in drylands, but are nevertheless characteristic of some wetlands, typically but not always on the fringes.

Species are presented in groups based on growth form and reliance on free water. Some groups are also separated by taxonomic group (e.g. grasses are separated from sedges and rushes). The groupings are fairly loose as some species do not fall easily into them. They are designed to assist non-botanists in developing an awareness of the key wetland plants. A single heading is used for each major growth form of woody perennials (trees, tall shrubs, medium shrubs, low shrubs and sub-shrubs) without subdivision according to tolerance of inundation.

Common names are given where they are reasonably well known or usefully descriptive.

Introduced plant species (weeds) are discussed in chapter 16 on wetland management issues.

Aquatic Herbs

There are about 19 arid NT species that fit our definition of aquatic (see section 9.4). Most of these are floating or submerged in water. Two are tall emergents: a grass, *Phragmites australis* (Common Reed), and *Typha domingensis* (Bullrush or Cumbungi). Another emergent is *Carex fascicularis*, a sedge that grows on the edge of pools along a single permanent stream in the study area (populations outside arid NT may be semi-aquatic). Many of the floating or submerged aquatics are rare and some are only known from permanent or semi-permanent waterholes. Some species included here can persist on wet soil when waters recede, but are included here because they predominantly occur as aquatics and can carry out their entire lifecycle without a dry phase.

Phragmites australis (Common Reed) is a true aquatic that requires permanent water. It is restricted in the arid NT, being only known from the Finke River System in the MacDonnell, Krichauff and James Ranges and from the springs of Watarrka in the George Gill Range. It is the only native water reed in the arid NT (reeds are tall aquatic grasses with hollow jointed stalks).

Myriophyllum verrucosum is the most widespread and common of the aquatic plants in the arid NT. Strictly, it is amphibious rather than a true aquatic, because it can persist in wet soil without free water. However, in the arid NT it is predominantly found growing submerged in riverine rockholes and waterholes with low salinity, and both in permanent and temporary waterholes. It has a feathery appearance and looks similar to another *Myriophyllum* species that is used widely in aquariums (*M. aquaticum*). It does not require permanent water but generally occurs in waterholes where there are semi-permanent or permanent waterholes upstream in the same drainage, from which it can recolonise. In the temporary waterholes of the Davenport Ranges, it progressively colonises the waterholes, from the edges, following wet season flows most summers. There is anecdotal evidence from Peter Latz that fifty years ago it was absent from the upper Finke River (upstream from Running Waters) (P.Latz pers. comm.). Currently it is abundant in those sections, possibly indicating a change in the river to make it more suitable for *Myriophyllum*. However, an old photograph of a waterhole in the Finke River at Henbury by Baldwin Spencer in 1897, shows dense aquatic vegetation which appears to be *M. verrucosum*. Interestingly, it is absent from Illara waterhole, on the Palmer River section of the Finke system.

Ruppia tuberosa is the other submerged aquatic vascular plant with feathery leaves. A monocot, it is widespread but typically occurs in temporary lakes and can tolerate saline waters. At Lake Lewis it was abundant in water with a conductivity measured at 32,000 μ S/cm, which is approaching the salinity of seawater (51,500 μ S/cm). *Ruppia* plants are primarily rooted in the substrate but may be able to persist as free floating plants if they become detached. *Ruppia* plays a vital role in providing food for wetland birds

(P.Latz & R.Jaensch pers. comm.), either as a direct food source or as a foundation for invertebrates. A brief discussion of the distribution and environmental tolerances of *R. tuberosa* and other Australian *Ruppia* species is given by Brock (1985). Brock (1985) also discusses another genus of salt tolerant submerged plants, *Lepilaena*, which does not occur in the NT.

A second species of *Ruppia*, *R. maritima*, is known from the study area but only from artificial waterbodies.

Nymphaea species (Water lilies) are characterised by large rounded floating leaves (lily pads) and lotus like flowers on emergent stalks. In the arid NT they have a highly restricted distribution limited to waterholes in the Barkly Tableland (upper Georgina River system, including the James River), and to Wycliffe Creek at Thring Swamp. There is some uncertainty about the taxonomy of these populations, but the Barkly Tableland species may be *Nymphaea gigantea*, whilst the Wycliffe one may be *Nymphaea immutabilis*.

Nymphoides species are occasionally referred to as water lilies due to a general resemblance to *Nymphaea* species. There are three species of *Nymphoides* known in the study area and all have highly restricted distributions and co-occur with *Nymphaea* spp. *Nymphoides aurantiaca* is known from waterholes in the James River area of the Barkly Tableland. *Nymphoides indica* (Fringed Waterlily or Water Snowflake) is only recorded in the study area from Thring Swamp near Wycliffe Well. *Nymphoides crenata* (Wavy Marshwort) is recorded in the study area from both areas. At least some species of *Nymphoides* can persist for some time on wet mud at the waters edge, so strictly speaking they are semi-aquatics.

Ottelia ovalifolia (Swamp Lily) is an aquatic plant that is restricted to permanent and semi-permanent water. Despite its common name of Swamp Lily, it is not closely related to either *Nymphaea* or *Nymphoides*, being monocotyledonous (along with grasses and sedges). It is very rare in the study area, being restricted to two areas. One is in the Krichauff Ranges, in and around Palm Valley, and the other is in the George Gill Range, in and near Kings Canyon. Typically only a few plants have been observed in an area or waterhole, but hundreds were observed at a series of waterholes in upper Palm Creek in 2001 (D.Schunke pers. comm.). Anecdotal evidence suggests that it mostly grows in summer (D.Schunke pers. comm.).

Two species of *Najas* (water nymphs or naiads) occur in the arid NT; both are submerged aquatic herbs that are usually associated with long lasting water. They are both rare in the arid NT. *Najas marina* is known from two permanent waterholes in the Finke River system. *Najas tenuifolia* is known from a single natural wetland in the study area, a temporary swamp filled from the Elkedra River. It is also known from a dam in the west of the Burt Plain Bioregion. Neither species was encountered during this study.

Two species of Eel grass occur in the study area: *Vallisneria annua* and *Vallisneria nana*. These are monocotyledonous herbs that grow in long-term freshwater environments. In this inventory, *V. annua* was recorded from two long lasting waterholes in the east of the Davenport Ranges, including one in a river system with no known permanent waterholes. It was also recorded in a sparsely wooded floodout swamp to the north of the Davenport Ranges.

Three species of *Potamogeton* (pondweeds) occur in the study area: *P. crispus*, *P. pectinatus* and *P. tricarinatus*. All are strictly aquatic, and are rooted in the substrate with either floating (*P. tricarinatus*) or submerged leaves. However, Brock and Casanova (1997) classified *P. tricarinatus* as amphibious in the NSW New England Tablelands. All three species are strongly associated with long-term waterbodies but do not seem to require permanent water. *P. pectinatus* is only known in the study area from artificial water bodies. *P. crispus* is rare, being only known from four localities: Finke Gorge, Heavitree Gap, the Frew River, and Tarlton Downs Station on the Plenty River (possibly in an artificial wetland). *P. tricarinatus* is relatively widespread with records from the Chewings Range, the north side of Mount Zeil, Palm Valley, the George Gill Range, the Dulcie Ranges and Muranji Rockhole in the Great Sandy Desert (GSD) Bioregion. The occurrence at Muranji is the only record of a fresh water aquatic plant in the NT portion of the GSD bioregion. Muranji Rockhole is known to dry out (e.g. 1996 as reported by Wischusen 1998) as have most waterholes in the George Gill Range but *P. tricarinatus* has been repeatedly observed there, indicating some ability of seeds or vegetative parts to survive without free water. Also, the occurrence of *P. tricarinatus* in open stock water tanks indicates that it is probably dispersed by waterbirds. Accordingly, it is considered as a moderate indicator of long-term water bodies. The continuing presence of *P. crispus* at Heavitree Gap in the Todd River indicates a probable ability of

that species to survive periods of desiccation; either as seed or as dormant vegetative parts. The waterhole in the gap is often dry although the sediments are more often damp than wet; partially due to irrigation (runoff and elevated water table) in Alice Springs. The species was first recorded there following a prolonged wet period in the mid 1970s and was present again following a similar wet period in 2000-2002. The relative rarity of this species in the region counts against the likelihood that it recolonised in 2000-2002, although the possibility of dispersal by birds cannot be discounted. In 2001, Peter Latz searched Boggy Hole thoroughly for *P. crispus* without finding it, although the species has previously been found there. A dense population of *Myriophyllum verrucosum* was present and could have outcompeted *P. crispus* (P.Latz pers. comm.).

Table 17. Summary table of Aquatic Plants

Growth Form / Species name	Reliance on Surface Water	Dicot/Monocot/Fern
Predominantly Submerged Feathery Leaves		
<i>Ruppia tuberosa</i>	strong	Monocot
<i>Ruppia maritima</i> ♣	strong	Monocot
<i>Myriophyllum verrucosum</i>	mod.	Dicot
Predominantly Submerged & Leaves Not Feathery		
<i>Vallisneria annua</i>	strong	Monocot
<i>Vallisneria nana</i>	strong	Monocot
<i>Potamogeton crispus</i>	strong	Monocot
<i>Potamogeton pectinatus</i> ♣	strong	Monocot
<i>Najas marina</i>	strong	Monocot
<i>Najas tenuifolia</i>	strong	Monocot
Predominantly Floating Leaves		
<i>Potamogeton tricarinatus</i>	strong	Monocot
<i>Ottelia ovalifolia</i>	strong	Monocot
<i>Nymphaea gigantea</i>	strong	Monocot
<i>Nymphaea immutabilis</i>	strong	Monocot
<i>Nymphoides crenata</i>	strong - ?mod.	Monocot
<i>Nymphoides aurantiaca</i>	strong - ?mod.	Monocot
<i>Nymphoides indica</i>	strong - ?mod.	Monocot
Emergent		
<i>Carex fascicularis</i>	strong in arid NT	monocot (sedge)
<i>Phragmites australis</i>	v. strong	monocot (grass)
<i>Typha domingensis</i>	strong-mod.	monocot (bullrush)

♣ = Australian native but only known from artificial water bodies in the arid NT

Semi-aquatic Herbs

Semi-aquatic plant species are defined here as those for which mature plants can thrive for extended periods in free surface water but can also thrive in drier conditions. Inundation is required for some stage of the life cycle, typically including germination. There is a clear distinction between semi-aquatics and other species that require inundation to germinate and may tolerate some subsequent inundation but do not thrive in water. However, for many species there is insufficient ecological knowledge to determine whether they are semi-aquatic or non-aquatic wetland plants.

Marsilea species (Nardoo) are semi-aquatic fern allies with distinctive fronds shaped like clover leaves, which may be emergent or floating during inundation. Seven species are known in the arid NT. They are mainly distinguished from each other by their reproductive structures, which are called sporocarps and are located towards the base of the fronds. One species, *M. latzii*, is moderately salt tolerant and is rare. Many of the species readily grow in highly temporary water bodies such as very small clay depressions;

however, *M. mutica* may favour longer term and more frequently inundated wetlands. Standing water is probably required for the spores of all species to germinate, and many or all species thrive in shallow water for extended periods of many months.

Isoetes muelleri is a fern-like plant that is semi-aquatic or amphibious (Cowie *et al.* 2000) but has more of the appearance of a grass. It may not require free water to complete its life cycle.

Bolboschoenus caldwellii is a semi-aquatic sedge that may require permanently waterlogged soil. It is rare in the arid NT, known from just four places.

Pseudoraphis spinescens (Swamp Grass, Spiny Mudgrass, Water Couch) is a semi-aquatic grass that floats on the surface of water in fresh water swamps and riverine pools. It can form dense swards on the banks of waterholes and can be easily confused with the invasive weed *Cynodon dactylon* (Couch or Lawn Couch).

Eragrostis australasicus (Swamp Canegrass) is a structural dominant of some wetland habitats of claypans and swamps, forming large, sometimes tangled clumps, typically about 1.5m tall. It is particularly characteristic of stony claypans in the south west.

Persicaria lapathifolia is common in sandy rivers of the MacDonnell Ranges Bioregion, to which it is restricted in the arid NT. It is erect with fleshy stems and happily tolerates inundation in temporary waterholes. According to Peter Latz, this species was absent from the upper Finke River before fifty years ago but is now abundant in the Finke, Hugh and Todd Rivers. The species was collected by Winkworth in 1954 at Palm Valley. Interestingly, like *Myriophyllum* it is absent from Illara waterhole, a permanent waterhole on the Palmer River tributary of the Finke.

Rotala species are typically found in damp soil adjacent to water and occasionally in shallow water. It is assumed that they germinate in response to inundation and reach maturity after water has receded. The degree to which they can thrive in water is unknown, and it is likely that some or all species do not qualify as semi-aquatic under our definition.

Table 18. Summary table of Semi-aquatic Plants

Growth Form / Species name	Initial Reliance on Surface Water	Dicot/Monocot/Fern
Predominantly Floating Leaves in Aquatic State		
<i>Marsilea</i> spp. (7 species)	strong	Ferns
<i>Pseudoraphis spinescens</i>	?strong	monocot (grass)
Emergent in Aquatic State		
<i>Bolboschoenus caldwellii</i>	?	monocot (sedge)
<i>Eragrostis australasicus</i>	?	monocot (grass)
<i>Eriachne benthamii</i>	?	monocot (grass)
<i>Juncus</i> spp.	?weak	monocots (rushes)
<i>Persicaria lapathifolia</i>	?mod.	Dicots
Erect Leaves – Submerged or Emergent in Aquatic State		
<i>Isoetes muelleri</i>	mod. - ?weak	Fern
<i>Rotala</i> spp.	mod. - ?weak	dicots

Non-aquatic Graminoids - Sedges and Rushes

Sedges (Cyperaceae) and rushes (Juncaceae) are grass like plants (graminoids) that are not members of the grass family (Poaceae). Some are quintessential wetland plants, growing as emergents from water, whilst others occur on the fringes of wetlands and in areas where water has receded. They typically occur in freshwater wetlands but a few tolerate some salinity. Some sedges (Cyperaceae) do not grow in wetlands at all. Here, three other monocotyledonous families are include loosely under ‘non-aquatic graminoids’: Typhaceae (bullrushes), Juncaginaceae and Eriocaulaceae (pipeworts).

Typha domingensis (Bullrush or Cumbungi) is the tallest member of this group and is a true aquatic plant. It occurs in long-lasting fresh water wetlands, but as it appears to be a good coloniser, it does not necessarily indicate permanent water.

The group known as rushes has one genus in the arid NT: *Juncus* (Juncaceae) with 4 native species (and two introduced ones). *Juncus* species are semi-aquatic. All of the native *Juncus* spp. are moderately tall, typically greater than 30cm. In the arid NT all the native species occur predominantly in long-term wetlands and wetlands which experience relatively frequent inundation. *Juncus* spp. were recorded in several sandy rivers that were dry on the surface but may have had shallow water tables due to hyporheic flow.

Juncus aridicola (Tussock Rush) and *Juncus continuus* occur in several bioregions within the arid NT. However, populations of both are highly localised. *Juncus kraussii* subsp. *australiensis* is salt tolerant and is relatively common in coastal salt marshes. In the NT it is confined to the MacDonnell Ranges Bioregion where it is relatively uncommon, being restricted to saline and semi-saline environments. *Juncus* A87739 MacDonnell Ranges is probably endemic to the MacDonnell Ranges Bioregion, however, within it is the most common of the four species. All four are only known to the south of 22° latitude.

There are a great many wetland sedges (Cyperaceae) in the study area, and only the grass family has more wetland species (Poaceae). Cyperaceae includes wetland species of *Baumea*, *Bolboschoenus*, *Bulbostylis*, *Carex*, *Cyperus*, *Eleocharis*, *Fimbristylis*, *Fuirena*, *Isolepis*, *Lipocarpha*, *Schoenoplectus*, *Schoenus*, and *Scleria*. The species range in size from a few centimetres to between 50 and 100 cm and encompass a range of requirements for and tolerance of inundation. Some species form perennial tussocks, some have bulbous rootstock from which they can resprout, whilst others are annuals. Some species are widely distributed and are highly characteristic of certain wetland types, whilst others are rare. *Eleocharis papillosa* (Dwarf Desert Spike-rush) is nationally listed as vulnerable and is endemic to the arid NT.

Triglochin (Juncaginaceae) includes three species in the arid NT. These are tufted annual plants found in floodouts and on the margins of claypans. One species, *Triglochin hexagonum*, is moderately salt tolerant.

There are three species of *Eriocaulon* (Eriocaulaceae) in the arid NT. Commonly known as pipeworts, they are distinctive small (< 15 cm) herbs with leaves typically in a rosette from the base and seed heads that form a single tight ball on erect stalks rising above the rosette. Some species in the Top End of the NT may be aquatic or semi-aquatic, but in the arid NT, they are probably all annuals that develop in receding water or wet soil post-inundation.

Non-aquatic Grasses

A great many grass species occur in wetlands. Many species are ubiquitous while some fall within our broad definition of wetland plants. A selection of those that are characteristic of some wetlands and some that are structural dominants are discussed here.

Imperata cylindrica (Bladey Grass) is a structural dominant of a few small swamps and in the arid NT is restricted to a few permanent or near permanent springs in the MacDonnell Ranges bioregion plus the Dulcie Ranges in the Burt Plain bioregion. It apparently has a high requirement for moisture but not inundation and therefore is not listed as a semi-aquatic.

Leptochloa digitata (Umbrella Canegrass) is a tall erect grass found on the edges of waterholes and also in swamps. It can be visually prominent but does not provide dense cover for birds.

Eulalia aurea (Silky Browntop) often dominates the banks of larger watercourses and waterholes and some swamps but is under severe competition from the introduced pasture grass *Cenchrus ciliaris* (Buffel Grass).

Dichanthium sericeum (Silky Bluegrass) dominates some swamps, typically those that are relatively briefly inundated. It also occurs in watercourses.

Several species of *Eriachne* are dominant plants in some wetlands. *Eriachne benthamii* s.lat. (Swamp Wanderrie) forms moderately dense small grassy swamps in parts of the south of the study area. Other species occur in creeks and swamps in the north.

Elytrophorus spicatus (Spikegrass) is a distinctive small erect grass with high fidelity to wetlands, typically freshwater swamps. Another genera of small erect grasses, with high fidelity to wetlands, is *Ectrosia* (Hares-foot Grass) with three species in the arid NT.

There are 22 species of *Eragrostis*, some of which are very common in wetlands including *E. dielsii*, *E. falcata*, *E. setifolia*, *E. basedowii*, *E. cumingii*, *E. elongata*, *E. tenellula* (s.lat), *E. parviflora*, *E. leptocarpa*, *E. kennedyae* and *E. speciosa*.

Other genera of common wetland grasses include: *Themeda*, *Leptochloa*, *Digitaria*, *Cymbopogon*, and *Chloris*.

Sporobolus virginicus (Salt Couch) is a salt tolerant species that is common in coastal salt marshes but only has a sparse distribution in the arid NT, occurring at a few saline springs and on the edges of some salt lakes. *Eragrostis falcata* is the most salt tolerant grass in the arid NT and is a common element in the vegetation of saline wetlands. In saline environments it typically has an annual life-form although it may be perennial in less saline conditions (P.Latz pers. comm.).

Low non-aquatic forbs

There are a great variety of wetland plants that typically establish in moist soil on the edges of receding waterbodies, be they swamps, claypans, river beds, river banks or waterholes. This group includes many species that do not tolerate extended inundation but may require it for germination.

Several species grow flat to the ground and form mats with creeping stems. These include several *Bergia* species, *Elatine* spp. including *E. gratioloides*, *Glinus* spp., *Cressa australis* and *Dentella* spp. *Elatine gratioloides* was classified as amphibious in a study in the New England Tableland of NSW (Brock & Casanova 1997).

A number of non-aquatic wetland herbs are members of the family Asteraceae (daisies) which includes *Centipeda* spp., *Gnaphalium diamantinensis*, *Pseudognaphalium luteoalbum*, *Pterocaulon sphacelatum*, *Sphaeranthus indicus*, *Sphaeromorphaea australis* and some species of *Streptoglossa* and *Pluchea*.

Isotoma luticola is a characteristic wetland plant that is now known to be more common than previously realised, as a result of this inventory. Four species of sundew (*Drosera* species) occur but predominantly *D. burmanni* and *D. indica*. Several species of the family Euphorbiaceae are characteristic of wetlands including *Phyllanthus virgatus*. Other common wetland herbs include several *Alternanthera* spp., *Lotus cruentus*, *Trigonella suavissima*, *Hypericum gramineum*, *Centaurium spicatum*, some species of *Frankenia* and *Goodenia*, *Basilicum polystachyon*, *Mimulus prostratus* and *M. gracilis*, *Peplidium*, *Stemodia*, *Ammannia multiflora* and *Macgregoria racemigera* (Desert Snow).

Persicaria decipiens is known from a single small long-term swamp on the south side of the George Gill Range.

Tall non-aquatic forbs

A group of plants of tall forbs characterise some swamps in periods following inundation, as they thrive in water logged soil, often forming dense stands of over two metres tall. They are all members of the pea family, Fabaceae, and several species are widespread across the study area. *Aeschynomene indica* (Budda Pea) can have a quick life cycle and is often seen as desiccated standing stalks. It has fine, pinnate leaves and highly characteristic small seed pods, which readily snap between each segment. Other tall pea bushes include some species of *Cullen* (previously called *Psoralea*). Not all *Cullen* species have high fidelity to wetlands but most at least have some affinity. *Cullen australasicum* (Tall Verbine) and *Cullen cinereum* (Annual Verbine) are the most characteristic and widespread, sometimes covering large areas of swamp.

Trees

Four species of *Eucalyptus* are by far the most abundant of arid NT wetland trees, dominating the vegetation of most drainage lines and many swamps. They are:

Eucalyptus camaldulensis var. *obtusa* (River Red Gum);

Eucalyptus coolabah subsp. *arida* (Coolabah);

Eucalyptus victrix (Smooth-barked Coolabah); and

Eucalyptus barklyensis (Barkly Coolabah).

E. camaldulensis is the most widely distributed of all Australian Eucalypts. In the arid NT it is almost always associated with water courses and occasionally floodouts, with the size of the trees generally corresponding to the size of the watercourse, but frequently reaching 25 metres. In the arid NT it typically occurs in sandy soils but also on rockier substrates.

E. coolabah, *E. victrix* and *E. barklyensis* are part of the group of species separated from *E. microtheca* (Hill & Johnson 1994). They can be reasonably tall trees in the order of 15 to 20m but often occur with a smaller dominant stand height, particularly *E. victrix*. All three are usually found on clayey or silty soils. *E. barklyensis* is quite distinct, growing mainly on river banks in the Mitchell Grass Downs bioregion and having persistent rough fissured bark. By contrast, *E. victrix* and *E. coolabah* subsp. *arida* have overlapping distributions, occupy similar environments and appear to intergrade in morphology. They are indistinguishable by their fruit, being separated only by the height of persistent bark. *E. victrix* occurs to the north of the tropic of Capricorn. It is essentially smooth barked, with a basal stocking of rough bark, typically only to 1m up the trunk and rarely to 3m (Hill & Johnson 1994). *E. coolabah* extends north of the tropic line but occurs mainly to the south. It typically has rough persistent bark the full height of the trunk and on the major and some minor branches. However, the persistence and thickness of the rough bark is quite variable. Where the distributions overlap there are often but not always intermediate forms with rough bark persisting to various heights on the main trunk. Both species have strong fidelity to wetlands but also occur in non-wetland environments. In the north of the study area, *E. victrix* often occurs in open woodlands on plains that have few other wetland species. Possibly, heavy rainfall events in the monsoon season create sheet flow across the landscape that is sufficient to support seedling establishment. Despite its presence in marginal wetland environments, *E. victrix* was encountered as dominant in many more long-lasting wetlands than the other wetland *Eucalypts*. This may indicate a relatively high tolerance of inundation.

Corymbia flavescens, a species closely related to Ghost Gum, is an emergent or dominant in some of the floodout swamps on the north side of the Davenport Ranges. The species was recorded from two wooded/shrubby floodouts, which are relatively infrequently inundated and which apparently hold surface water only briefly.

Erythrina vespertilio (Bean Tree, Bats Wing Coral Tree) is a frequent but never dominant tree of the bigger watercourses to the north of the MacDonnell Ranges but does also occur away from wetlands.

Lysiphyllum gilvum (Bauhinia) occurs next to waterholes and other riverine habitats in the north of the study area. It usually co-occurs with other species such as *Eucalyptus barklyensis* and *Acacia georginae*.

Livistona mariae subsp. *mariae* (Red Cabbage Palm) is only known from the Finke River and its tributaries in and near to Palm Valley and downstream to Running Waters. Although this taxon has a very restricted distribution, it is a well known and interesting wetland plant.

Tall Shrubs and Shrubby Trees

Tall shrubs are often features of riverine wetlands and the fringes of swamps and claypans. Occasionally they form an overstorey in temporary swamps. The predominant genera are *Melaleuca* and *Acacia*.

Most species of *Melaleuca* in the study area are strongly associated with wetlands. They are features of wetlands across most of the study area apart from the higher rocky hills and the Simpson Desert (P.Latz pers. comm.). Many creeks have more than one species present and some have three (e.g. *M. dissitiflora*, *M. bracteata* and *M. glomerata* all grow in the same reach of Trephina Creek).

Melaleuca glomerata (Inland Tea-tree) is the most common. It occurs within and on the banks of rivers and creeks, paleodrainage areas, and on the fringes of claypans, swamps and salt lakes. It also forms quite extensive low shrublands on plains in the vicinity of salt lakes and sometimes claypans, in areas that are rarely inundated. This is probably due to its moderate tolerance of salinity and the fact that such plains have a relatively high water table, without being swamps.

Melaleuca bracteata (Black Tea-tree) and *Melaleuca dissitiflora* (Creek Tea-tree) are both associated predominantly with creeks and rivers. *Melaleuca bracteata* occurs only in the MacDonnell Ranges and Burt Plain Bioregions. *M. dissitiflora* is more common in the north of the study area and is the dominant *Melaleuca* species of creeks and rivers in and flowing out from the Davenport Ranges. However, it also occurs in the Petermann Ranges in the far south west of the arid NT and in the Musgrave Ranges in South Australia. It is strongly associated with higher nutrient rocks such as granites and gneisses.

Melaleuca viridiflora (Green or Broad-leaved Paperbark) occurs in the north of the study area and is a co-dominant in a section of the combined floodout of the Frew River and Teatree Creek. It is easily distinguished by its broad leaves and green bottle brush flower spikes. Compared to *M. dissitiflora* and *M. bracteata* it has a lower fidelity to wetlands within the arid NT.

Melaleuca uncinata (Broom Honey Myrtle) is a distinctive species with hooked, needle-like leaves. It has a central and western distribution in the study area, but in this inventory it was only encountered in the Petermann Ranges.

Melaleuca trichostachya (Narrow-leaved Paperbark) is restricted to drainage lines and the banks of waterholes in the MacDonnell Ranges Bioregion. This is the most restricted of the *Melaleuca* species in the study area.

Callistemon pauciflorus is a tall shrub restricted to waterholes of the MacDonnell Ranges Bioregion in the centre of the study area, and the Central Ranges Bioregion, in the south west. It is the only arid NT *Callistemon*; a common wetland genus in south eastern Australia.

Acacia stenophylla (River Cooba) is a low shrubby tree that is the dominant or co-dominant (with *Eucalyptus barklyensis*) overstorey species in a few of the minor creeks in the Mitchell Grass Downs Bioregion. To the north of the study area it occurs extensively in vast swamps of the Barkly Tableland.

Acacia salicina is an overstorey species of some river banks and is a significant component of the floodout 'forest' (thickets) of the Finke River, extending to the South Australian border. It grows to quite a tall tree.

Acacia cyperophylla (Mineritchie) is a distinctive tall shrub or tree with attractive curly red bark. This species almost always occurs in or adjacent to drainage lines. In the study area it has a very restricted distribution: Toko Ranges, Allitera Tableland, and the Stony Plains Bioregion on the South Australian border.

Acacia dolichophylla is a smaller, erect shrub that only grows in minor drainage lines in and below the Chewings Ranges. There is a group of *Acacias* (Wattles) that is common in, and somewhat characteristic of, the drainage lines in the northern part of the study area, although none is restricted to wetlands. They are *Acacia neurocarpa*, *Acacia colei*, *Acacia cowleana* (Halls Creek Wattle), *Acacia holosericea* (Candelabra Wattle) and *Acacia elachantha*. These five related species grow as relatively open shrubs up to about 4 m tall. They can be hard to distinguish, and the diagnostic features are beyond the scope of this report.

Acacia farnesiana, *Acacia georginae* (Gidgea) and *Acacia aneura* (Mulga) are all characteristic species in some wetlands but are also widespread in dryland habitats and are not wetland species under our definition. *A. farnesiana* is a frequent element of river bank vegetation and some swamps, across much of the study area. It is a shrub with dense thorns that appears to be favoured by disturbance, natural or otherwise. Its habitat and pinnate leaves resemble several noxious weeds of the Mimosaceae family (*Acacia nilotica*, *Mimosa pigra* and *Prosopis pallida*), and it is often treated as a weed by landholders. *Acacia georginae* (Gidgea) is a species that is widespread across the landscape in the east of the study area and is frequent along the banks of waterholes and drainage lines. *A. aneura* is an occasional element of the vegetation fringing rivers, swamps and claypans, although it is usually intolerant of extended inundation. It was the dominant species as a tall shrub or low tree in one floodout swamp encountered in

the survey, and in some other swamps, it was the dominant species of fringing vegetation and had apparently been inundated for periods of several months.

Medium Sized Shrubs

There are several wetland species of compact shrubs of medium size (0.5 – 2 m) in the study area. The two with highest tolerance of inundation are *Chenopodium auricomum* (Northern, Queensland or Swamp Bluebush) and *Muehlenbeckia florulenta* (Lignum). Both species predominantly occur in fresh water swamps and sometimes occur with a Coolabah (*Eucalyptus coolabah* and *E. victrix*) overstorey. In the arid NT there are numerous large swamps dominated by *C. auricomum*, and such areas are commonly described as Bluebush swamps. *C. auricomum* also occurs as a minor element in some other swamps. *Muehlenbeckia florulenta* is also widespread but rarely occupies such large areas. *M. florulenta* often occurs in the overflow swamps adjacent to drainage lines and along side channels, where as *C. auricomum* is rarely found along watercourses. *C. auricomum* is possibly more drought tolerant than *M. florulenta*, since many Bluebush swamps often go many years between major inundation events.

Chenopodium auricomum should not be confused with the various species of *Maireana* for which 'Bluebush' is a common name, but which are predominantly dryland species.

Chenopodium nitrariaceum can have a similar appearance to *C. auricomum*, and they co-occur at some wetlands. *C. nitrariaceum* is typically smaller and is distinguished by tangled spinose branch ends. The distribution of *C. nitrariaceum* is essentially restricted to the south west quadrant of the arid NT. It may form the dominant shrub cover over some swamps, but there is little data to confirm this.

Two other species that occasionally form the dominant shrub layer of swamps are *Atriplex nummularia* subsp. *nummularia* (Old Man Saltbush) and *Maireana aphylla* (Cottonbush, Leafless Bluebush). Both frequently occur outside swamps and probably only occur in very rarely inundated areas.

Typical medium to tall shrubs, of drainage systems, include *Myoporum acuminatum* (Boobiella) and *Dodonaea viscosa* subsp. *mucronata*.

Cullen leucanthum and *Cullen walkingtonii* form dense stands in some floodouts and swamps in the north.

Small Shrubs and Sub-shrubs

There are a great many small shrubs and sub-shrubs which occur in or fringing a wide variety of wetland types. Some of the more common and characteristic ones are described here.

There is a group of succulent leafless sub-shrubs of the genus *Halosarcia* (Chenopodiaceae) that dominate some saline swamps, and are often collectively referred to as samphire. Other wetland genera related to *Halosarcia* are *Sclerostegia* and *Tecticornia*. *Sclerostegia tenuis* sometimes grows on salt lake margins and *Tecticornia verrucosa* occurs on fresh water claypans and has a scattered distribution in the western half of the study area. All of the above species are moderately tolerant of inundation and could be classed as semi-aquatic.

Other important chenopod genera in both saline and fresh swamps are *Atriplex*, *Maireana*, *Sclerolaena*, and *Dysphania*.

Lawrenzia glomerata s.lat. is a common on the fringes of saline lakes. *Lawrenzia squamata* also occurs in saline environments and indicates the presence of gypsum.

Ludwigia octovalvis is an erect semi-woody annual that frequently grows on the edges of waterholes in and around the Davenport Ranges.

Teucrium racemosum is a moderately tall growing perennial (> 20 cm) that is abundant in many swamps in the central and particularly the southern latitudes of the study area.

Ferns of Shaded Moist Gullies and Gorges

About eleven species of fern in central Australia are restricted to mesic environments. Most are only known from relatively deep shaded gorges, but a few occur in association with running streams in moderately shaded gullies. Some grow in areas of saturated soil, while others are only known from seepage areas on rock walls with typically just a few plants. These latter are at the smallest end of the size spectrum of wetlands, but the dependence of the ferns on free water justifies their inclusion as wetlands. A few species may not require seepage, only deep shade, and so are not considered to be wetland plants nor indicators of micro-wetlands. Different species and groups of species are found in each moist gorge, and the extent to which this a result of random survival and dispersal histories, as opposed to habitat differences between gorges, is not known.

Non-vascular Wetland Plants

Non-vascular wetland plants can be important in the overall biological productivity (Bunn & Davies 2001) but were not systematically sampled in survey work. Descriptive comments were recorded at detailed survey sites, concerning the abundance and habit of algae and some specimens were opportunistically collected. Forms of non-vascular plants commonly observed in arid NT wetlands include:

- filamentous algae such as *Chara spp.* and *Nitella spp.*;
- floating slime;
- submerged algal blooms;
- algae that coat rocks and plants stems .

9.5 Vegetation Assemblages

A national perspective on wetland vegetation is important for assessing the conservation importance of regional populations and assemblages. Brock (1994) gives a good overview of the nature and types of aquatic environments for plants in her chapter on aquatic vegetation of inland wetlands, in *Australian Vegetation* (Groves 1994).

Hatton and Evans (1997) review the dependence of Australian ecosystems on groundwater and include a useful summary of the vegetation of broad ecosystems. Information on wetland vegetation of the arid NT can be found in their appendix A, including physiographic descriptions for several broad geographic areas: 'The Central Lowlands and the South Australian Ranges', 'Arid Areas of Uncoordinated Drainage', 'Sandland', 'The Lander-Barkly Plains', and 'The Central Australian Ranges'. Hatton and Evans (1997) also provide broad vegetation descriptions for various wetland vegetation types, based largely on Briggs (1981).

9.6 Conservation Significance of Arid NT Plants

A full list of plants of conservation significance was collated in 2000 (White *et al.* 2000a), which also recorded the occurrence of each species in broad wetland types.

There are 10 species of vascular wetland plants that are endemic to the arid NT or a slightly larger area:

- Acacia dolichophylla* (R)
- Coleocoma centaurea*
- Eleocharis papillosa* (V)
- Goodenia A44284 Subsaline* (K)
- Goodenia D70208 Barkly* (K)
- Juncus A87739 MacDonnell Ranges* (V)
- Livistona mariae subsp. mariae* (V)

Marsilea latzii (R)

Pluchea A87409 Ormiston (K)

Stemodia A57025 Manners Creek (K)

A further 24 plants that occur in wetlands are endemic to the arid NT or slightly larger area but have unknown fidelity to wetlands.



10. Fishes in the Arid NT

Scope

Fish are an important group of fauna in wetlands of arid areas, providing a measure of the availability of permanent water. The presence of fish can also indicate that swamps or lakes are connected to river systems when connections are not mapped or obvious from channels.

This section is a review of the distributions of fish species in the arid NT, based on pre-existing distribution data and new data collected during the 2001 wetland survey. Survey methods and results are reported. A summary of the taxonomy and distribution of each species is included plus a review of the distribution of fishes by drainages. Various aspects of fish ecology, habitat and distribution in the arid NT are discussed. Readers are directed to other sources for further information on those subjects and for identification guides.

The term 'indigenous' and 'native' are applied to fishes to mean naturally occurring (not released by people); as distinct from Australian native fish that have been translocated to the arid NT which are treated here as 'introduced'.

10.1 Methods

Sampling

A permit to collect aquatic life was obtained from the then NT Government Department of Primary Industries and Fisheries.

Fish were sampled opportunistically at sites where they were observed or suspected to occur. Sampling effort varied widely depending on available time. The methods used were:

- seine netting – several nets were used, with mesh sizes aimed at simultaneously sampling macro invertebrates and fishes, all about 2 to 3 m wide by 1 to 2 m high and constructed from curtain netting or from shade cloth and operated by two people;
- cast netting – 6 foot cast net;
- pole/dip netting, sometimes in conjunction with rock turning;
- line and hook;
- drop nets; and
- trapping with net cage traps and funnel traps.

Specimens were identified in the field using Larson and Martin (1990) and Wager and Unmack (2000) as a guide. Specimens were taken of all species caught at a site for subsequent confirmation of identifications by museum staff. Multiple specimens of each species were collected for genetic analysis at the South Australian Museum. The number kept was up to 20 individuals, depending on local abundance and capture success. Fish specimens were euthanised in a clove oil solution of approximately 1-2ml / 500ml of water and were preserved by one of three methods:

- freezing in electric (12 volt) car fridge/freezer;
- fixing in formalin solution, made up of 10% formaldehyde in demineralised water; or
- a solution of 70% ethanol and 30% water.

Storage of Specimens

Specimens that were fixed in formalin and subsequently stored in 70% ethanol will be variously kept as part of a reference collection or lodged with the NT Museum. The frozen and ethanol-preserved specimens were lodged with the 'Australian Biological Tissues Collection' at the South Australian Museum.

Collaboration with Deakin University and South Australian Museum

Two researchers from Deakin University took part in two of the field trips: Bernadette Bostock and Stephen Ryan. Their participation was part of a joint project of the South Australian Museum and Deakin University. The scope of that project is described below based on information from Mark Adams at the South Australian Museum.

The project is using several molecular genetic techniques to examine species boundaries, evolutionary relationships, and population structure in the desert fishes of Australia. That information will then be incorporated into a comprehensive Geographic Information System (GIS) of the freshwater systems. Localities with the most vulnerable faunal diversity will be identified, setting priorities for conservation action. The project is supported by the Australian Research Council SPIRT grants scheme and the Australia and Pacific Science Foundation.

Bernadette Bostock was conducting research for a doctorate on the evolution, biogeography and status of desert fish, as part of the above research project.

Sources of Distribution Data

Distributions of species by drainage system were determined using point data, collated into a geographical information system (GIS), and various reports and publications, as listed below.

Museum specimen records were obtained from the following institutions: Northern Territory Museum; South Australian Museum; Western Australian Museum; Museum of Victoria; Queensland Museum; and the Australian Museum. The identity of some specimens may require verification (H. Larson pers. comm.). It is expected that some other institutions in Australia and overseas may have specimens from the arid NT. Also, some of the museums from which records were obtained may have uncatalogued specimens. Several Australian institutions with fish collections (as listed in the internet site of AMOL - Australian Museums On Line) were not contacted: Museum of Tropical Queensland; Tasmanian Museum and Art Gallery; Queen Victoria Museum (in Tasmania); and the CSIRO Division of Marine Research (in Tasmania).

Errors were identified in the geocodes (location coordinates) for some records and where possible corrected. In some cases, records had not been re-determined to reflect recent taxonomic developments. For the purpose of mapping species distributions, these records were allocated to the most probable contemporary species. Some specimen records could not be allocated with any certainty.

Additional point records were obtained from the Central Australian Wildlife Collection database. Many, but not all, records are duplicated by data from the NT Museum which took over curation of the Central Australian Wildlife Collection in the 1980s.

The survey work conducted in 2001 for the inventory of wetlands of the arid NT resulted in 112 specimens from 59 sites in 15 drainage systems. This apparently included new species records for some catchments: *Neosilurus hyrtlii* in Kurundi Creek; *Nematalosa erebi* and *Porochilus argenteus* in the Sandover River; and *Leiopotherapon unicolor* from the Hanson River, Wycliffe Creek and Murray Creek.

An unpublished summary of fish survey work on the Finke River (Saxon *et al. in litt.*) was obtained. Some specimens from that work were lodged with the NT Museum, and the unpublished summary data are consistent with species distributions as determined from various museum specimen records.

Storrs and Finlayson (1997) list two databases for fish records in NT wetlands held by H.Larson at the Northern Territory Museum: 'Fishspec' and 'Fishstat' data bases. It is assumed that these were the source of data provided by the Northern Territory Museum (by Helen Larson).

Various reports record the presence of fish species at particular sites. Bishop and Moses (1983), Bishop and Larson (1983) and Johnson *et al.* (1984) report on fish surveys in the Davenport and Murchison ranges region, including a summary table of species by drainage system in Bishop and Larson (1983). Bishop and Larson (1983) cite a historical paper (Central Australian Exploration Syndicate 1905) from which they interpreted observations by Alan Davidson in the Bonney Creek area in 1898. Bishop and Moses (1983) also present the results of opportunistic fish survey in the Davenport Ranges by Latz and Howe in 1970.

Latz and Langford (1983) and Gibson *et al.* (1989) recorded fish in the Dulcie Ranges.

Fogarty *et al.* (1995) recorded six species of fish in the Toko Range portion of the Georgina River system.

Davis (1995) conducted an aquatic fauna survey of waterholes in the West MacDonnell Ranges.

Unmack (1995) sampled fish in various arid NT rivers, and Unmack (1995, 2001a) discusses distribution records from various sources.

Wager and Unmack (2000) provide a checklist of species in the (greater) Lake Eyre Basin by drainage basin, which was used as the basis for the Georgina River list in this report. They also document various introductions and occurrences of non-indigenous species.

Analysis of Distributions and Migration Opportunities

Species distributions and opportunities for migration between catchments were analysed using digital and hard copy topographic maps, a digital elevation model (DEM), river basin boundary mapping and satellite imagery. The topographic maps were those published at 1:1000,000 and 1:250,000 scales and raster images of unpublished 1:100,000 National Mapping compilation material, scanned by Geoimage. The DEM was the AUSLIG Geodata 9 second DEM version 2, with an approximate cell resolution of 278m. The satellite imagery was Landsat ETM+ from wet periods in 2000 and 2001, with a combination of full images and internet 'Quicklook' images which have degraded spectral and spatial resolution.

10.2 Fish Species of the Arid NT

All species that are known to occur in the wild in the arid NT, or have occurred in the past, are listed in table 19 below. A few species are included for which there are no confirmed records, but which are known from river systems that extend into the arid NT. The table is ordered alphabetically by family name, genus and species, in groups based on natural distribution.

Table 19. Known and possible fish species of the arid NT.

Scientific Name	Family	Common Names
Group 1. Native to arid NT (species for which there may be taxonomic uncertainty are marked †)		
<i>Ambassis</i> sp. (central Australia) †	Ambassidae	Glassfish, Northwest Glassfish, Central Australian Glassfish [?]
<i>Craterocephalus centralis</i>	Atherinidae	Finke River Hardyhead, Finke Hardyhead
<i>Nematalosa erebi</i>	Clupeidae	Bony Bream
<i>Mogurnda larapintae</i>	Eleotridae	Finke Mogurnda, Desert Mogurnda, Purple-spotted Gudgeon, Finke River Gudgeon [?]
<i>Mogurnda</i> sp. (Davenport Ranges) †	Eleotridae	Davenport Ranges Mogurnda [?] , Frew Mogurnda, Purple-spotted Gudgeon, (Finke Mogurnda)
<i>Chlamydogobius japalpa</i>	Gobiidae	Finke Goby
<i>Glossogobius aureus</i> †	Gobiidae	Golden Goby
<i>Melanotaenia splendida subsp. tatei</i>	Melanotaeniidae	Desert Rainbowfish
<i>Macquaria</i> sp. (Lake Eyre)	Percichthyidae	Lake Eyre Golden Perch, Yellowbelly
<i>Neosilurus hyrtlilii</i> †	Plotosidae	Hytrl's Catfish
<i>Porochilus argenteus</i>	Plotosidae	Silver Tandan, Silver Catfish
<i>Amniataba percoides</i>	Terapontidae	Banded Grunter
<i>Leiopotherapon unicolor</i>	Terapontidae	Spangled Grunter, Spangled Perch
<i>Scortum barcoo</i>	Terapontidae	Barcoo Grunter, Black Bream
2. Native to Australia – Possible natural occurrence in arid NT (Georgina River)		
<i>Bidyanus welchi</i>	Terapontidae	Welch's Grunter
3. Native to Australia – Natural occurrence in NT unlikely but possible (not known in the NT but could occasionally occur in NT tributaries of the Macumba River in sustained wet periods and in the Finke River if joined to the Macumba by a mega flood)		
<i>Craterocephalus eyresii</i>	Atherinidae	Lake Eyre Hardyhead
<i>Chlamydogobius eremius</i>	Gobiidae	Desert Goby
4. Native to Australia – Introduced or possibly[‡] introduced in arid NT		
<i>Maccullochella peelii</i> [‡]	Percichthyidae	Murray Cod, Mary River Cod
<i>Macquaria ambigua subsp. ambigua</i>	Percichthyidae	Murray-Darling Golden Perch, Yellowbelly
<i>Bidyanus bidyanus</i> [‡]	Terapontidae	Silver Perch, Bidyan
5. Exotic – Introduced to Australia (only <i>Gambusia</i> are extant[‡])		
<i>Cyprinodontidae</i> sp.	Cyprinodontidae	Killifish
<i>Perca fluviatilis</i>	Percidae	Redfin, European Perch
<i>Gambusia</i> spp. (<i>holbrooki</i> [‡] , <i>affinis</i> & <i>dominicensis</i>)	Poeciliidae	Mosquito Fish, <i>Gambusia</i> , Eastern <i>Gambusia</i>
<i>Phaloceros caudimaculatus</i>	Poeciliidae	Speckled Mosquitofish, One-spot Livebearer
<i>Xipophorous helleri</i>	Poeciliidae	Swordtail

The common names in the table are those in most popular use, plus preferred or suggested new names; the latter being marked [?]. A summary of the distribution and naming of each species is presented in a subsequent section of this chapter, in the same groupings as the above table and including additional common names and scientific synonyms.

There are 13 native species that have a confirmed natural and contemporary occurrence in the arid NT. This number may be increased by taxonomic revision of *Ambassis* (Glassfish), *Mogurnda* (Davenport Ranges population) and *Neosilurus*. Taxonomic review of these is required or in progress according to

Allen *et al.* (2002) and may result in the recognition of distinct species for one or more of the isolated arid NT populations. There is one other native species that may occur in the NT portion of the Georgina River, being recorded elsewhere in that river system, but is unconfirmed by museum specimens for the NT portion: *Bidymanus welchi* (Welch's Grunter). There are two native species that probably do not occur in the NT but were previously thought to be in the Finke and could sporadically occur in the NT in upper tributaries of the Macumba River. There are three species of Australian native that have been introduced, at least one of which is persisting. There are four or five species of fish exotic to Australia that have been released in the wild, of which only one is known to have a self sustaining population.

Taxonomic Authorities

There is no single authority on currently accepted scientific names for Australian freshwater fish. The Zoological Catalogue of Australia publication series has published one of two intended volumes on fishes (Paxton *et al.* 1989). However, the authors emphasise in the introduction that the fishes section of the Catalogue is in a relatively preliminary stage. Various organisations maintain internet lists of species but cannot be relied on to include the latest taxonomic changes. The Australian Faunal Directory (AFD) is an 'online' database being created by the Australian Biological Resources Study (ABRS) group of Environment Australia (Commonwealth Government). The Australian Faunal Directory incorporates the Zoological Catalogue of Australia (internet site of AFD). Some groups have been given Biocodes, with fishes included, in *Codes for Australian Aquatic Biota* (CAAB) for aquatic organisms, maintained by the CSIRO Division of Marine Research (internet sites of ABRS & CAAB). The Australian Museum maintains 'The Australian Species List' (internet site of AMOL-fishes). It is currently a modification of the June 1998 version of CSIRO's CAAB list but is also linked to the specimen collections held in Australia. Most of these are housed in museums. Native Fish Australia (NFA), a volunteer organisation, also presents a species list on its internet site (internet site of NFA). Our list of scientific names largely follows recent identification guides by Wager and Unmack (2000) and Allen *et al.* (2002).

The common names in table 19 are those that have most usage in the arid NT or usefully distinguish the species. Several new names are suggested. Other common names encountered in reference books are listed in a subsequent section which summarises the distribution of each species and lists synonyms. Common names are sometimes used very loosely and caution is urged in interpreting local information about the presence of fish species. For example, some pastoralists appeared to use the term Bony Bream to refer to a variety of native fish. There may sometimes be some deliberate vagueness due to an intention to 'muddy the waters' with regard to unauthorised introductions of popular angling species.

10.3 Temporal Terminology

The terminology used to describe the temporal arrangement of fish habitats is described here.

There are various uses of the term 'permanent' as applied to the persistence of water in riverine waterholes or other wetlands. Unmack (2001a) includes as permanent those which are known to have occasionally dried out. We use a stricter definition such that permanent waterholes are those that have always held at least some surface water in recorded or oral history (as discussed in Chapter 5). They may have continuously held water during the period of current climatic conditions, in the order of 2000 to 10,000 years. However, data on past climate variations and extreme floods and droughts is sparse, and extreme droughts may have occurred for which there is no historical equivalent (past 100-150 years).

Waterholes which are known to have dried out but which usually hold water continuously for many years, are described here as 'long-term', which equates to the use of 'perennial' for waterhole persistence. We recognise four categories of persistence of long-term waterholes, including permanent ones, based on the frequency with which they dry out completely. This approach follows Unmack (2001a) who used three categories.

Our categories are:

Permanent - not known to ever completely dry out;

Semi-Permanent - only dries out in the most severe droughts in the order of once in 50 years or less frequently;

Rarely Dry - usually inundated but dries more frequently than semi-permanent, in the order of once in 10 to 40 years;

Occasionally Dry - usually inundated but dries out several times a decade, more frequently than once in 10 years.

10.4 Historical Perspective

The history of the scientific investigation of fishes in central Australia has been covered by various authors, with varying geographic areas of interest. Here, we summarise from them for the arid NT, focusing on systematic surveys and reviews, whilst acknowledging the importance of various opportunistic collections and observations made by many different people.

The Horn expedition in 1894 was the first systematic scientific survey of central Australia and collected six fish species from the Finke River, which was sampled at various localities. Four of these species were new to science and were described by Zeitz in the report on the expedition (Zeitz, 1896). Prior to the expedition, only three species were recorded from central Australia (Unmack 1995). Davis (1996) reviewed the collections and contributions of the 1894 Horn expedition to central Australia, in the light of subsequent survey and taxonomic work; however, there have been some taxonomic clarifications even since 1996.

Glover and Simm (1978b) presented a thorough historical review of discoveries and observations of central Australian fishes. They note that extensive collections were made by the Arid Zone Research Institute (Alice Springs) in the late 1960's. Glover and Simm (1978a) present a preliminary checklist for major drainage systems in central Australia, and Glover (1982) provided a provisional checklist by drainage basin for the Lake Eyre Drainage and Western Plateau Divisions, revised from Glover and Simm (1978a). However, there was very little systematic fish survey in the arid NT that was not in the Finke River system, prior to work in the Davenport and Murchison Ranges in 1993 (Bishop & Moses 1983; Bishop & Larson 1983).

Unmack (2001a) provides the most recent and comprehensive review of fish distributions in the Finke and other south flowing river systems of the Alice Springs region (Todd, Hale, and Hay-Plenty) and Unmack (1995) gives a summary of past ichthyological work in central Australia in a conference paper on Australian desert fishes, which includes a summary of the contributions of recent and contemporary workers. Some additional information on the distribution of species by drainage systems is provided by Wager and Unmack (2000) in their book on fishes of the Lake Eyre Basin.

10.5 Review of Naming and Distribution of Each Species

In this section we summarise the naming and distribution of each species. Synonyms for scientific names and families are given to assist with analysis of historical records. All known common names are listed in addition to those that are recommended here. Aranda language Aboriginal names are given for some species of the Finke River. These have been taken from a Conservation Commission public information sheet listing fishes of the Finke River and were apparently supplied by Graham Griffin who had worked as a ranger at Palm Valley. Distribution is summarised by drainage system or sub-system. Notes on behaviour and habitat are included for some species.

Group 1: Native To Arid NT

Ambassis sp. (central Australia) [Ambassidae]

Glassfish, Northwest Glassfish

Arid NT Distribution: Known from: the Finke River system; the Georgina River (Barkly Tableland and Toko) Ranges; the Sandover River (Ooratippra Creek in the Dulcie Ranges); and Whistleduck Creek system (Davenport Ranges).

General Distribution: According to Allen *et al.* (2002), there is one or more undescribed species of *Ambassis* which occurs in the Kimberley Region, northern NT and central Australia including western Queensland.

Taxonomy & Synonyms: According to Allen *et al.* (2002) all central Australian records of *Ambassis* are of one or more undescribed species, referred to here as *Ambassis sp. (central Australia)*. It is possible that the arid NT populations may be genetically distinct from each other, particularly the Finke River population. Wager and Unmack (2000) state that all previous records of *Ambassis castelnaui* for central Australia are now applicable to *A. mulleri*, which are treated here as *Ambassis sp. (central Australia)*. Larson and Martin (1990) give *Blandowskiella castelnaui* as a synonym for *A. mulleri*. Merrick and Schmida (1984) describe *Ambassis castelnaui* (Macleay, 1881) as occurring in the Lake Eyre Drainage Division and Bishop and Moses (1983) also refer to that species. *Ambassis agrammus* only occurs in coastal areas of the Top End of the NT and the east coast of Cape York (Allen *et al.* 2002) and any records from the arid NT are treated here as *Ambassis sp. (central Australia)*. Frozen and alcohol preserved specimens from the arid NT wetlands survey will assist genetic research (all arid NT populations sampled, but Ooratippra Creek specimens in alcohol, not frozen).

Common Name Usage: Allen *et al.* (2002) use Northwest Glassfish. Any reference to Glassfish, Sail-fin Glassfish, Chanda Perch and Sail-fin Perchlet in the arid NT are presumably *Ambassis sp. (central Australia)*. If a new species is described with a solely arid distribution, then an appropriate common name would be Central Australian Glassfish or Desert Glassfish.

Craterocephalus centralis (Crowley & Ivantsoff 1990) [Atherinidae]

Finke River Hardyhead, Finke Hardyhead,

Arid NT Distribution: Restricted to the Finke River system (endemic to the arid NT). Davis (1996) reports that it appears to be restricted to pools in the upper Finke system. However, specimens in the South Australian Museum were collected by Terry Simm and others from Horseshoe Bend in 1997 and also from the Hugh River near Maryvale Homestead in 1976. In our 2001 survey it was collected near Idracowra Homestead and Horseshoe Bend Homestead in the mid-reaches of the Finke.

Taxonomy & Synonyms: *Craterocephalus centralis* was described as a distinct species by Crowley and Ivantsoff (1990), separating it from *C. eyresii*. *C. centralis* is now thought to be the only *Craterocephalus* in the Finke River system (Wager & Unmack 2000). Accordingly all records of *Craterocephalus* in the Finke River system should be treated as *C. centralis*. Larson and Martin (1990) recognised the Finke species as distinct under their description of *C. eyresii* for which they list *C. cuneiceps* as a synonym. At that time it was believed that the undescribed species (now *C. centralis*) had an overlapping range with that of *C. eyresii* in the Finke River. The 1980 Conservation Commission Species list of Finke fishes lists this species as *Craterocephalus fluviatilis*.

Common Name Usage: Allen *et al.* (2002) use Finke River Hardyhead whereas Wager and Unmack (2000) use Finke Hardyhead. Desert Hardyhead has been used as a common name for Hardyheads in the Finke River but is ambiguous as it could also refer to the Lake Eyre Hardyhead (*C. eyresii*). Larson and Martin (1990) give Desert Hardyhead as a second common name for *C. eyresii* and Merrick and Schmida (1984) also have Central Australian Hardyhead. Both these names may be encountered in reference to *C. centralis* but should not be used to avoid confusion with *C. eyresii*.

Conservation Status: The Action Plan for Australian Freshwater Fishes (Wager & Jackson 1993) lists *C. centralis* as 'Rare'. The Australian Society for Fish Biology list it as 'Restricted' with an IUCN category of 'Lower Risk - near threatened' in their 'Australian Threatened Fishes 1999 Supplement'.

Nematalosa erebi (Gunther 1868) [Clupeidae]

Bony Bream

Arid NT Distribution: Known from 4 drainages in the arid NT: Finke, Georgina, Sandover and Whistleduck systems. The only vouchered records for the Sandover River system (this survey) are from Junction Waterhole at the junction of the Sandover and Bunday rivers. Bishop and Larson (1983) recorded it in Whistleduck Creek but not in any other of the other Davenport ranges systems. In the arid NT it appears to be in a similar number of drainage systems to *Melanotia splendida subsp. tatei* (5) and *Amniataba percoides* (4). In many years it is observed dead on the surface and edges of water bodies in large numbers following fish kills.

General Distribution: Widespread across northern and inland Australia, including the Murray River system. Wager and Unmack (2000) state that it is the equal second most widespread native fish in Australia (giving *Leiopotherapon unicolor* as the most widespread and *Neosilurus hyrtlui* as the equal second).

Taxonomy & Synonyms: Larson and Martin (1990) list *Chatoessus erebi* and *Chatoessus horni* as synonyms. The 1980 Conservation Commission Species list of Finke fishes lists Bony Brim as *Fluvialosa hornii*.

Common Name Usage: Larson and Martin (1990) give Bony Bream and Freshwater Herring. The use of Freshwater Herring is not recommended due to potential confusion with *Potamalosa richmondia*. Wager and Unmack (2000) use only Bony Bream. Lake (1978) uses Bony Bream and Hairback Herring. Merrick and Schmida (1984) also give Hairback Herring and list additional regional names: Tukari, Pyberry and Melon Fish. Unmack (1995) and others also use Gizzard Shad. Although spelt with 'ea' the vowel sound in Bream is generally pronounced with an 'i' to sound like the brim of a hat. Aranda name: Intipinya.

Mogurnda larapintae (Zietz 1896) [Eleotridae]

Finke Mogurnda, Desert Mogurnda, Purple-spotted Gudgeon, Finke River Gudgeon

Arid NT Distribution: Probably restricted to the Finke River system (endemic to the arid NT) where it is known from the upper Finke, Palmer River and mid-Finke sections of the drainage system. Allen *et al.* (2002) state that the most southerly record is Running Waters (upper Finke), but South Australian Museum records extend the range into the mid-Finke section (probably Stuart Highway bridge). We collected or observed the species in shallow water in a long-term but temporary stony pool in upper Ellery Creek (abundant) and in dense rushes, reeds and sedges at Two Mile Waterhole above Glen Helen Gorge (abundant). It is not recorded from the Hugh River section of the Finke drainage system.

General Distribution: The group of fishes previously known as *Mogurnda mogurnda* is widespread in northern Australia. Mogurndas can climb out of the water and Larson and Martin (1990) note that because they are capable of leaping and climbing, Mogurndas are sometimes found as the sole species in upper pools. There is no reported incidence of this result in the arid NT and there are many anecdotes of *Leiopotherapon unicolor* also jumping well. However, further survey, particularly in the upper Palmer River and upper Finke River sections of the Finke system may reveal *M. larapintae* as the sole occupant of upper pools.

Taxonomy & Synonyms: The *Mogurnda* genus was recently reviewed by Allen and Jenkins (1999). They recognised three distinct species which had previously been included under *Mogurnda mogurnda*. The Finke Mogurndas have reverted to the earliest specific name which was applied by Zietz to specimens from the Finke River from the 1896 Horn Expedition (Davis 1996): *Eleotris larapintae* (Zietz 1896). Larson and Martin (1990) list *Eleotris mogurnda* as a synonym. The *Mogurnda* populations in the Frew River and Whistleduck Creek are under taxonomic review and may be closest to *M. larapintae*, *M. mogurnda* or could be a distinct undescribed species.

Common Name Usage: Allen *et al.* (2002) use Desert Mogurnda for *Mogurnda larapintae*, where as Wager and Unmack (2000) use Finke Mogurnda and Purple-spotted Gudgeon. The latter is the name used for *Mogurnda mogurnda* (in the broad sense), e.g. by Larson and Martin (1990) and Lake (1978). Merrick and Schmida (1984) list the name Northern Trout Gudgeon as well as Purple-spotted Gudgeon for *M. mogurnda*. Wager and Jackson (1993) use Northern Trout Gudgeon for *Mogurnda mogurnda*. In the latest book about inland fish, Allen *et al.* (2002) use Purple-spotted Gudgeon for *Mogurnda adspersa* of eastern Australia and Northern Trout Gudgeon for *M. mogurnda* of the Top End of the NT and Cape York. We recommend the use of Finke Mogurnda and Finke River Gudgeon (suggested 'new' name 'Desert Mogurnda' should be avoided due to the potential confusion with other arid zone Mogurndas such as *M. clivicola*).

Conservation Status: This taxon was given a conservation code of 'restricted' by the Australian Society for Fish Biology using its classification system.

Mogurnda sp. (Davenport Ranges) [Eleotridae]

Davenport Ranges Mogurnda, Frew Mogurnda, Purple-spotted Gudgeon, Northern Trout Gudgeon

Arid NT Distribution: This may be a new species restricted to the Frew River and Whistleduck Creek on the north side of the Davenport Ranges. Mogurndas can be hard to catch and further survey in other drainages of the Davenports are warranted. The Frew River and Whistleduck Creek are isolated from each other and from rivers of the actual Barkly Tableland. Most records are from the mid to upper sections of the two drainage systems from both shallow temporary pools and deeper permanent ones (Bishop & Larson 1983; and our survey data). We also collected specimens from a swamp in the floodout of the Frew River.

Taxonomy & Synonyms: The Mogurndas of the Davenport Ranges are part of the species group previously known as *Mogurnda mogurnda* (e.g. in Larson & Martin 1990). Affinity to other Mogurndas is under review (Wager & Unmack 2000) and frozen specimens from the Frew River (this survey) should provide a basis for determining their taxonomic status using genetic techniques. Allen *et al.* (2002, p.308) include Mogurndas of the Davenport Ranges under *M. mogurnda* (Northern Trout Gudgeon) as applied to populations of the Top End and Cape York but note that the 'population on the Barkly Tableland may eventually prove to be a separate species'. NT Museum specimen records are currently listed as *M. larapintae*.

Common Name Usage: Purple-spotted Gudgeon is the name used for *Mogurnda mogurnda* (in the broad sense), e.g. by Larson and Martin (1990) and Lake (1978). Allen *et al.* (2002) use Northern Trout Gudgeon for *M. mogurnda* in the revised sense. Wager and Unmack (2000) use 'Frew Mogurnda' for the potentially distinct species of the Davenport Ranges, for which we propose 'Davenport Ranges Mogurnda' as a more useful common name.

Conservation Status: If distinct from other recently described species then this taxon would certainly merit a conservation code of 'restricted' under the Australian Society for Fish Biology classification system.

Chlamydogobius japalpa (Larson 1995) [Gobiidae]

Finke Goby

Arid NT Distribution: Restricted to the Finke River system (endemic to the arid NT), where it is the only Goby present (Wager & Unmack 2000). Various authors state that it is only known from the upper Finke River (Larson 1995; Wager and Unmack 2000; Allen *et al.* 2002). However, specimens in the South Australian Museum are from the mid-Finke, as far down stream as the new railway bridge on Idracowra Station. Collections from our survey extend its known range further downstream to Horseshoe Bend.

Taxonomy & Synonyms: *C. japalpa* has been recently distinguished from *Chlamydogobius eremius* (Larson 1995). According to Larson (1995) the two species are morphologically similar and are very close genetically but are consistently morphologically distinct. The name 'japalpa' comes from the Western Aranda name for the part of the Finke River also known as Glen Helen Gorge (Larson 1995).

Common Name Usage: Previously included under Desert Goby (*C. eremius*) but now a separate species. Wager and Unmack (2000) and Allen *et al.* (2002) give Finke Goby as the common name. Davis (1996) uses Finke Desert Goby.

Conservation Status: Vulnerable (Territory Parks and Wildlife Act). The Australian Society for Fish Biology list it as 'Restricted' with an IUCN category of 'Vulnerable' in their 'Australian Threatened Fishes 1999 Supplement'.

Glossogobius aureus (Akihito & Meguro 1975) [Gobiidae]

Golden Goby

Arid NT Distribution: Barkly Tableland portion of the Georgina River system according to museum records where it is relatively abundant according to Wager and Unmack (2000).

General Distribution: It is widespread throughout coastal northern Australia and the Indo-pacific region, but in the Lake Eyre Region is only known from the Georgina River (Wager & Unmack 2000). However, Allen *et al.* (2002) do not show any inland distribution for this species and note that it has a marine larval stage.

Taxonomy & Synonyms: there is some doubt about the identity of specimens of Gobiidae from the NT portion of the Georgina River system. Museum records of three specimens were obtained; listed as either *Glossogobius aureus* or '? *Glossogobius aureus*' (NTM & Aus.Mus.). Further investigation is warranted into the origin and ecological and possible genetic distinctiveness of the Georgina River population. Unmack (1995) refers to the Gobiidae species in the Georgina River as *Glossogobius giurus* (Hamilton 1882).

Melanotaenia splendida subsp. tatei (Zietz 1896) [Melanotaeniidae]

Desert Rainbowfish

Arid NT Distribution: Known from 5 drainage systems: the Finke, Sandover (only Ooratippra Ck), Georgina, Frew and Whistleduck Creek. Unmack (2001a) reports a 1979 record by Glover for the Todd River, but subsequent sampling has not resulted in new records so it may have only temporarily occurred in the Todd, possibly following an aquarium release.

General Distribution: This sub-species occurs in the Lake Eyre drainages plus Lake Woods and the Barkly Tableland Rivers (Larson & Martin 1990).

Taxonomy & Synonyms: Larson and Martin (1990) give *Nematocentris tatei* as a synonym. Davis (1996) gives *Nematocentris winnecki* as another synonym.

Common Name Usage: The common name is unambiguous when used in full. Locally the common name is often abbreviated to just Rainbowfish which is the name used for *Melanotaenia splendida* in the broad sense (all sub-species) and many members of other species and genera of Melanotaeniidae. Aranda name: Tnumatnumu.

Macquaria sp. (Lake Eyre) [Percichthyidae]

Lake Eyre Golden Perch, Yellowbelly

Arid NT Distribution: Barkly Tableland portion of the Georgina River system (based on records of NT Museum specimens currently identified as *Macquaria ambigua*).

General Distribution: Georgina River, Diamantina River and Cooper Basin (Wager & Unmack 2000).

Taxonomy & Synonyms: According to Wager and Unmack (2000), this species has been recognised as distinct from *Macquaria ambigua*, but not yet described. Allen *et al.* (2002) note genetic evidence that this may be a distinct species but describe it under the entry for *M. ambigua*.

Common Name Usage: Wager and Unmack (2000) give Lake Eyre Golden Perch, Yellowbelly and Callop as names for the Lake Eyre species. Yellowbelly and Golden Perch are the names generally used locally.

Neosilurus hyrtlilii (Steindachner 1867) [Plotosidae]

Hyrtl's Catfish

Arid NT Distribution: In the arid NT it is recorded for 6 drainages: the Finke River; the Georgina; and four of the north flowing Davenport and Murchison ranges rivers: Gosse Creek, Kurundi Creek, Whistleduck Creek and the Frew River. Suitable habitat for *N. hyrtlilii* occurs in the deeper long-term pools of the upper Ooratippra Creek in the Dulcie Ranges; an area that has not been adequately surveyed. Records for the Georgina River system, include a specimen caught in a clear waterhole in the Toko Ranges in the NT, for which the identity is unconfirmed. All waterbodies where it was caught during this survey were of low turbidity. Wager and Unmack (2000) note that *N. hyrtlilii* occurs in both muddy and clear water and is abundant in the Georgina River which is predominantly highly turbid. There are museum specimen records of *N. hyrtlilii* from the Barkly Tableland section of the Georgina River. Larson and Martin (1990) note that *N. hyrtlilii* co-occurs with *Porochilus argenteus* in the Newcastle Waters area, to the north of the arid NT. The colour of *N. hyrtlilii* is quite variable and previously it was thought that there were two species of catfish in the Finke River; one being dark and one light in colour.

General Distribution: Widespread across northern and inland Australia (Merrick & Schmida 1984). Wager and Unmack (2000) state that it is the equal second most widespread native fish in Australia, after *Leiopotherapon unicolor* as the most widespread and *Nematalosa erebi* as the equal second.

Taxonomy & Synonyms: Larson and Martin (1990) give *Copidoglanis glencoensis* as a synonym. Allen *et al.* (2002) note that the geographically separated populations of *N. hyrtlilii* may represent more than one species. Some survey and specimen records of *N. hyrtlilii* are recorded as *Neosilurus argenteus* due to past confusion with the Silver tandan (*Porochilus argenteus*).

Common Name Usage: Larson and Martin (1990) give Hyrtl's Catfish and Yellow-finned Catfish as common names for *N. hyrtlilii*. Wager and Unmack (2000) add Moony and Moonfish. Merrick and Schmida (1984) and Lake (1978) list it as Hyrtl's Tandan. Wager and Jackson (1993) give Hyrtl's Tandan as the primary common name and Glencoe Tandan as an alternative common name. Aranda names: Rrumunta and Rriynnginya.

Porochilus argenteus (Zietz 1896) [Plotosidae]

Silver Tandan, Silver Catfish

Arid NT Distribution: Common in the Georgina River system, including the arid NT portion and also confirmed for the Sandover River. An anecdotal record of a catfish in the Waite River section of the Sandover River system, from the mid 1970's, is likely to have been *Porochilus argenteus*, specimens of which were caught at Argadargada Waterhole in the floodout of the Sandover River (this survey). It is likely that these fish were recent migrants to the Sandover from the Georgina but alternatively they may have migrated from permanent pools in the Dulcie Ranges. Larson and Martin (1990) note that it is often found in turbid or milky water. Wager and Unmack (2000) state that all records of *P. argenteus* from the Finke River system are misidentifications of *Neosilurus hyrtlui*. Larson and Martin (1990) note that the two species co-occur in Newcastle Waters and there are museum specimens of both *N. hyrtlui* and *P. argenteus* from the Barkly Tableland section of the Georgina River.

General Distribution: Reasonably widespread in central and northern Australia including all the Queensland Lake Eyre drainages, the Macumba River in South Australia and the Barkly Tableland in the NT (Wager & Unmack 2000). Larson and Martin (1990) note that it is common in Newcastle Creek including Lake Woods.

Taxonomy & Synonyms: Larson and Martin (1990), Merrick and Schmida (1984) and Lake (1978) describe this species under the name *Neosilurus argenteus*, and Larson and Martin (1990) give *Plotosus argenteus* as a synonym. We have followed Wager and Unmack (2000) and Allen (1989) by using *Porochilus* which is consistent with the list of fish species names maintained by the Australian museums.

Common Name Usage: Larson and Martin (1990) give Silver Catfish and Central Australian Catfish as common names for this species. Allen *et al.* (2002), Wager and Unmack (2000) and Lake (1978) list it as Silver Tandan. Merrick and Schmida (1984) use Silver Tandan and Central Australian Catfish. It is recommended that the name Central Australian Catfish be avoided due to the physical similarity with *Neosilurus hyrtlui*, which also occurs in central Australia.

Amniataba percooides (Günther 1864) [Terapontidae]

Banded Grunter

Arid NT Distribution: In the arid NT it is widespread in the Finke and Georgina River systems, including the Toko Ranges, and in two drainages in the Davenport: Whistleduck Creek and Frew River.

General Distribution: Widespread through northern Australia (Merrick & Schmida 1984; Wager & Unmack 2000).

Taxonomy & Synonyms: Larson and Martin (1990) give *Therapon percooides* as a synonym.

Common Name Usage: Allen *et al.* (2002) gives Barred Grunter as the common name. Larson and Martin (1990) and the Native Fish Australia web site give Barred Grunter as a secondary name. However, the Australian Museum website gives this as the common name for *Pomadasyus kaakan* (Cuvier 1830). Merrick and Schmida (1984) give Black-striped Grunter as an alternative name. Lake (1978) gives Black-striped Grunter as the primary name and gives both Banded Grunter and Tiger Fish as alternative names. Aranda name: Intaminta

Leiopotherapon unicolor (Gunther 1859) [Terapontidae]

Spangled Grunter, Spangled Perch, Bobby Cod

Arid NT Distribution: In the arid NT, every drainage system with fish has *L. unicolor* even if no other species are present. The exceptional hardiness and dispersal abilities of this species are well known but as yet there is no firm evidence of an ability to survive periods without free surface water, either as dormant adults or eggs (e.g. Unmack 2001a).

General Distribution: *Leiopotherapon unicolor* is the most widespread native fish in Australia according to Wager and Unmack (2000).

Taxonomy & Synonyms: Larson and Martin (1990) list two synonyms: *Therapon unicolor* and *Therapon longulus*. Lake (1978) describes this species under the name *Madigania unicolor*. Davis (1996) records that the name used by the 1984 Horn expedition was *Therapon truttaceus*.

Common Name Usage: Larson and Martin (1990) and Merrick and Schmida (1984) give Spangled Grunter and Spangled Perch as common names. Allen *et al.* (2002) uses Spangled Perch. Wager and Unmack (2000) give Spangled Perch and Bobby Cod and Lake (1978) uses Spangled Perch and Jewel Perch. Spangled Grunter and Spangled Perch both have popular use in central Australia. Aranda name: Lungulpira.

Scortum barcoo (McCulloch & Waite 1917) [Terapontidae]

Barcoo Grunter, Black Bream

Arid NT Distribution: Georgina River. Museum records collated for this study include a single specimen from the NT portion of the Georgina River. However, the species is apparently common there (H.Nix pers. comm.).

General Distribution: Widespread from the Georgina to Bulloo rivers but mostly uncommon (Wager & Unmack 2000). Also recorded from the Barkly Tableland portion of the Barkly Basin (Wager & Unmack 2000; H.Nix pers. comm.).

Taxonomy & Synonyms: Larson and Martin (1990) list two synonyms: *Therapon barcoo* and *Scortum hilli*.

Common Name Usage: All sources use Barcoo Grunter, with Wager and Unmack (2000) also giving Black Bream which is ambiguous and so use is not recommended.

Group 2: Native to Australia – Possible Natural Occurrence in Arid NT (Georgina River)

Bidyanus welchi (McCulloch & Waite 1917) [Terapontidae]

Welch's Grunter

Arid NT Distribution: Possibly occurs in the arid NT part of the Georgina River.

General Distribution: Widespread from the Georgina to Bulloo rivers (Wager & Unmack 2000).

Common Name Usage: All sources use Welch's Grunter. Merrick and Schmida (1984) and Wager and Unmack (2000) also give Black Bream and Lake (1978) gives Black Bream and Silver Bream. Only the name Welch's Grunter is unambiguous and so is recommended.

Group 3. Native to Australia – Natural Occurrence in NT Unlikely but Possible

Craterocephalus eyresii (Steindachner 1883) [Atherinidae]

Lake Eyre Hardyhead

Arid NT Distribution: Not known in the NT. Could possibly occur on the South Australian border in upper tributaries of the Macumba River system in wet periods, when the Macumba is connected to the Neales River via Lake Eyre.

General Distribution: Occurs in South Australia in catchments of Lake Eyre (Neales River), Lake Torrens and Lake Frome (Wager & Unmack 2000).

Taxonomy & Synonyms: The name *Craterocephalus eyresii* was previously applied to the hardyheads in the Finke River but following the revision by Crowley and Ivantsoff (1990), the species now referred to as *C. eyresii* does not occur in the Finke. Larson and Martin (1990) list *C. cuneiceps* as a synonym.

Common Name Usage: Larson and Martin (1990) give Desert Hardyhead as a second common name. Merrick and Schmida (1984) also have Central Australian Hardyhead. Both these names should now be avoided due to the potential confusion with *C. centralis*.

Chlamydogobius eremius (Zietz 1896) [Gobiidae]

Desert Goby

Arid NT Distribution: Not known in the NT. Could possibly occur on the South Australian border in upper tributaries of the Macumba River system in wet periods, when the Macumba is connected to the Neales River via Lake Eyre.

General Distribution: Restricted to river systems that connect to Lake Eyre (Allen *et al.* 2002) where they are widespread (Wager & Unmack 2000). Extensive survey work following the 1974 floods did not locate *C. eremius* in Lake Eyre itself (Glover & Sim 1978). Wager and Unmack (2000) record it for the Neales River in South Australia, but not from the Macumba River, which just extends into the NT. Presumably it could migrate to the Macumba via Lake Eyre, during wet periods.

Taxonomy & Synonyms: The name *Chlamydogobius eremius* was previously applied to the gobies in the Finke River but following the revision by Larson (1995), the species now referred to as *C. eremius* does not occur in the Finke. *Gobius eremius* was the original name for *Chlamydogobius eremius* (Glover & Simm 1978a, as cited in Larson and Martin 1990).

Common Name Usage: Following the recognition of distinct species from Dalhousie Springs and the Finke River, a new common name that reflects the geographic distribution might be better (less ambiguous) for this species.

Group 4. Native to Australia – Introduced or Possibly Introduced in Arid NT

Macquaria ambigua subsp. ambigua (Richardson 1845) [Percichthyidae]

Murray-Darling Golden Perch, Yellowbelly

Arid NT Distribution: *M. ambigua subsp. ambigua* has been introduced to Whistleduck Creek according to Wager and Unmack (2000). A species of Yellowbelly has been introduced to the Elkedra River which is probably *M. ambigua subsp. ambigua* but could be *M. sp. (Lake Eyre)*. A species of *Macquaria* may also have been introduced to the Frew River. Merrick and Schmida (1984) state that *Macquaria ambigua* has been introduced into the NT. There is anecdotal evidence that at least the Elkedra population is persisting. Unmack (1995) records that a species of *Macquaria* was confirmed as occurring in Jervis Mine Dam, from photographs of fish caught there. As this dam dries out periodically the species will not persist unless re-introduced. There is a recent anecdotal report of *Macquaria sp.* stocked in a dam on Undoolya Station.

General Distribution: A native of the Murray-Darling drainage division (Wager & Unmack 2000).

Common Name Usage: Wager and Unmack (2000) give Murray-Darling Golden Perch, Yellowbelly and Callop. Yellowbelly and Golden Perch are the names generally used locally.

Maccullochella peelii (Mitchell 1939) [Percichthyide]

Murray Cod, Mary River Cod

Arid NT Distribution: Unmack 1995 records it for central Australia, and a station owner interviewed in this survey referred to fish he had caught in Hatches Creek on the Frew River as Cod.

General Distribution: A native of the Murray River system (*subsp. peelii*) and the Mary River in Queensland (*subsp. mariensis*). The Mary River sub-species is listed by the IUCN as critically endangered (Allen *et al.* 2002).

Bidyanus bidyanus (Mitchell 1838) [Terapontidae]

Silver Perch, Bidyan

Arid NT Distribution: Introduced to Whistleduck Creek on the north side of the Davenport Ranges according to Wager and Unmack (2000).

General Distribution: A native of the Murray-Darling drainage division (Wager & Unmack 2000).

Common Name Usage: Lake (1978) gives several other names in use: Bream, Black Bream and Silver Bream. Merrick and Schmida (1984) and Allen *et al.* (2002) both use only Bidyan and Silver Perch.

Group 5. Exotic – Introduced to Australia

***Cyprinodontidae* sp.** [Cyprinodontidae]

Killifish

Arid NT Distribution: Probably not persisting in the wild. Unmack (1995) reports a record of an unidentified species of Cyprinodontidae from Pine Gap dam from 1975.

General Distribution: Native to South America where habitats include temporary wetlands. Fertilized eggs can withstand partial dehydration during the dry season (Mills 1981).

Perca fluviatilis (Linnaeus 1758) [Percidae]

Redfin, European Perch

Arid NT Distribution: Probably not persisting in the wild. There is anecdotal evidence that *Perca fluviatilis* were introduced to Finke River in the 1950's (M.Lines pers. comm.) but no evidence that they have persisted there.

General Distribution: An exotic fish of European origin, it has a broad but patchy distribution in southern Australia (Merrick & Schmida 1984).

***Gambusia* spp. (*holbrooki*, *affinis* & *dominicensis*)** (Girard 1859) [Poeciliidae]

Mosquito Fish, Gambusia, Eastern Gambusia

Arid NT Distribution: There is an extant population of *Gambusia holbrooki* in the Alice Springs Sewage Ponds and adjoining Illparpa Swamp. Luckily the creek into which this swamp overflows is not known to join the nearby Todd River. Previously in the arid NT, Gambusias have been collected from the fish pond outside Flynn Church in Alice Springs and from John Hayes Rockhole in the Todd River system (possibly *Phaloceros caudimaculatus*), but were eradicated from both sites (Unmack 1995). Glover and Sim (1978) and Merrick and Schmida (1984) record that *Gambusia affinis* was dispersed throughout Australia before and during World War 2. Allen *et al.* (2002) describe another species, *Gambusia dominicensis*, that is poorly known and of similar appearance to *G. holbrooki*, and was apparently introduced in the vicinity of Alice Springs in the 1940s and 50s but may no longer persist. Larson and Martin (1990) state that both *G. affinis* and *G. dominicensis* were introduced to the NT in wartime. Unmack (2001a) notes that records of *G. dominicensis* from the Alice Springs area, as reported by Glover and Sim (1978a) and Glover (1982), may be referable to *Phaloceros caudimaculatus*.

General Distribution: *Gambusia holbrooki*, a native of Central and North America, is a serious and established pest in various Australian waterways. Contrary to its common name, introduced populations are ineffective in controlling mosquitoes. The Australian Museum website describes Gambusia and its highly invasive and destructive characteristics.

Taxonomy & Synonyms: Various reports of Mosquito Fish in Australian waters refer to *Gambusia affinis*, *Gambusia holbrooki*, *Gambusia dominicensis* and *Gambusia* sp.. Some articles and web sites refer to *G. affinis* and *G. holbrooki* as separate species, but these names may be synonymous.

Phaloceros caudimaculatus (Hensel 1868) [Poeciliidae]

Speckled Mosquitofish, One-spot Livebearer

Arid NT Distribution: Probably not persisting in the wild. Unmack (1995) cites a 1973 collection from Trepkina Gorge and a 1977 collection from John Hayes Rockhole, both part of the Todd River system. He records that the John Hayes population was subsequently poisoned. He also cites a 1982 record from Thompson, from the Flynn Church pond, in Alice Springs, in 1982. *Gambusia* sp. were recorded and eradicated from the Flynn Church pond in 2000.

General Distribution: Native to South America, this species occurs in south-western Western Australia (Merrick & Schmida 1984; Unmack, Australian Desert Fishes web pages).

Taxonomy & Synonyms: Some records of this may actually be *Gambusia* spp. and visa versa.

Common Name Usage: Allen *et al.* (2002) use only Speckled Mosquitofish whereas Merrick and Schmida use only One-spot Livebearer.

Xipophorous helleri (Gunther) [Poeciliidae]

Swordtail

Arid NT Distribution: Probably not persisting in the wild. Davis (1995) reports a record from a dam near the Pine Gap defence facility and Unmack (1995) cites a 1982 record of Thompson from the Todd River. There is no evidence of extant populations in arid NT.

General Distribution: This exotic species is established in various Queensland coastal drainages (internet site of Australian Desert Fishes) and one drainage in Western Australia (Allen *et al.* 2002).

Common Name Usage: Green Swordtail

10.6 Ancestry of Arid NT Fishes and Endemism

All of the arid NT native fishes are derived from marine ancestors, with strong affinities to Indo-Pacific marine fishes (Williams & Allen 1987, Boulton & Brock 1999, and Allen *et al.* 2002). Bishop and Larson (1983, p.11) cite a theory of McDowall (1981) that ‘most of northern Australia [including the Lake Eyre basin] has been colonised by a northern warm water fish fauna.’

The arid NT study area falls within two national drainage divisions as delineated by the Australian Water Resources Council (discussed in more detail in chapter 4): the Lake Eyre Drainage Division and the Western Plateau Drainage Division. The Lake Eyre Drainage Division includes catchments from which surface water no longer reaches Lake Eyre, such as the Finke River. Within the arid NT there are indigenous fishes in both drainage divisions; however, the arid NT species are virtually a subset of those in the Lake Eyre Drainage Division, based on current taxonomy.

There are three formally described species that are restricted to (endemic to) the arid NT as defined for this inventory. All three are currently considered to be endemic to the Finke system: *Chlamydogobius japalpa* (Finke Goby), *Craterocephalus centralis* (Finke Hardyhead) and *Mogurnda larapintae* (Finke Mogurnda or Purple-spotted Gudgeon). All three have close relatives in other drainages of the Lake Eyre Basin, from which they have presumably become differentiated by long-term isolation in the Finke River. The isolation of other species and populations may also have resulted in similar but currently undocumented differentiation. Little is known about the length of time of isolation and other selective forces for differentiation to occur in inland Australian fishes. The level of endemism in the Finke River is attributed to some combination of isolation and distinctive habitat. In comparison, Dalhousie Springs, an isolated wetland aggregation in the Macumba basin of South Australia, has six species of which five are endemic to these hot springs (Wager & Unmack 2001).

There are several taxa for which there is taxonomic uncertainty. *Mogurnda sp. (Davenport Ranges)* may be endemic to the Davenport Ranges sub-section of the Barkly Basin (Allen *et al.* 2002) or may prove to be closely related to currently recognised species when the taxonomic status is resolved; possibly *M. larapintae*. *Ambassis sp. (central Australia)* is the name used here for arid NT populations of *Ambassis* which may be recognised as one or more species (Allen *et al.* 2002). Thus the Finke and/or Whistleduck Creek populations might be endemic species of their respective drainages. Allen *et al.* (2002) note that isolated populations of *Neosilurus hyrtlilii* also warrant taxonomic review, which raises the possibility that populations of the Finke, Frew and Whistleduck Creek systems may each be sufficiently genetically distinct to be described as separate species or sub-species.

10.7 Summary of Species Diversity by Drainage Divisions, Basins and River Systems

Each of the national drainage divisions is subdivided into national drainage basins. A drainage basin may have one or several extensive drainage systems, as well as small isolated drainages. For some of the larger river systems we define sub-sections which have or currently appear to have different species assemblages.

The term drainage system is used here interchangeably with river system to refer to drainage channels that are connected by surface water in normal flow events. This includes connection by interim floodouts.

Lake Eyre Drainage Division

There are 13 indigenous fish species likely to occur in the arid NT portion of the Lake Eyre Drainage Division (12 confirmed), compared to 33 indigenous species listed for the entire drainage division by Wager and Unmack (2000). Taxonomic review of *Ambassis* and *Neosilurus* may result in additional numbers of species in the arid NT portion of the Lake Eyre drainage division, if the populations in the Finke system are found to be distinct from those in the Georgina system.

Within the NT portion of the Lake Eyre Drainage Division all four drainage basins, as delineated by the Australian Water Resources Council, have one or more drainage systems with fish. In the Georgina River

Basin, the Georgina River system has 10 or 11 species (one unconfirmed), and there is an anecdotal report of fish in the Field River, which is not mapped as connecting to the Georgina River. The Sandover River system is a distinct section of the Georgina system with surface water connection to the Georgina River in the order of once every ten years. Five species have been recorded in the Sandover system but it is likely that two of these do not persist in the Sandover and are only present following sporadic colonisation from the Georgina River.

In the Finke River Basin the Finke River system has 9 species.

The Todd River Basin has three major rivers. There is one extant indigenous species (*L. unicolor*) in the Todd River that may be a result of human translocation. There is a confirmed absence of fish in the Hale River (Gibson *et al.* 1992) and no information for Illogwa Creek.

In the Hay River Basin there is also a single indigenous species (*L. unicolor*) in the Plenty-Hay River system.

Western Plateau Drainage Division

There are 7 indigenous fish species in the arid NT portion of the Western Plateau Drainage Division, compared to 9 indigenous species listed by Wager and Unmack (2000) for the entire drainage division. There are fish in three of the five basins: the Barkly Basin with nine indigenous species; the Wiso Basin with one confirmed species; and the Burt Basin with one species. There are no fish in the Mackay or Warburton basins, which approximate the area known as the Western Desert and occupy roughly one quarter of the arid NT as defined for this study.

Of the drainage systems in the study area portion of the Barkly Basin, Whistleduck Creek has 7 species, the Frew River has 5 species, Kurundi Creek and the Gosse River both have 2 species, and the Elkedra River has one species.

Six drainage systems in the Wiso Basin have confirmed records of a single indigenous species (*L. unicolor*): Bonney Creek, McClaren Creek, Wycliffe Creek, Murray Creek system (including Skinner Creek), the Hanson River and the Lander River. The current populations in two of these are known to be a result of translocation. For Bonney Creek there is a historical record indicating that three species were present but only *L. unicolor* was recorded by a more recent systematic survey (Bishop & Larson 1983).

There are three drainages in the Burt Basin with confirmed occurrences of *L. unicolor*, all connected via surface flow to Lake Lewis: Napperby Creek, Day Creek and Dashwood Creek. It is probable that only the Day Creek population has a long-lasting drought refuge. It is likely that fish also occur in The Derwent and Gidyea Creek at least following connections to Lake Lewis, as discussed further below.

It is notable that there are many more drainages in which fish have been recorded in the Western Plateau Drainage Division (16) compared to the Lake Eyre Drainage Division (4).

Comparisons with Other Arid Australian Drainages

The species diversity of the arid NT is not high in global terms but is moderately high in terms of the Australian arid zone. For example, the most species rich basin within the greater Lake Eyre Basin is the Cooper Creek basin (19 taxa) with nearly twice as many species as are known from the Georgina River Basin, which is the richest arid NT drainage basin.

Table 20. Summary of indigenous species distribution by drainage system

River System (& Basin)	<i>C. centralis</i>	<i>N. erebi</i>	<i>Mog. larapintae</i>	<i>Mog. sp. Dav</i>	<i>C. japalpa</i>	<i>G. aureus</i>	<i>Mel. splendida</i>	<i>Mag. sp. L. Eyre</i>	<i>Mag. (translocated)</i>	<i>N. hyrtii</i>	<i>P. argenteus</i>	<i>A. percoides</i>	<i>L. unicolor</i>	<i>B. bidyanus</i>	<i>B. welchi</i>	<i>S. barcoo</i>	<i>Ambassis sp.</i>
Lake Eyre Drainage Division																	
Finke	Y	Y	Y		Y		Y			Y		Y	Y				Y
Field													A?				
Sandover		Y					Y				Y		Y				Y
Georgina		Y				Y	Y	Y		Y	Y	Y	Y		Q	Y	Y
Plenty/Hay													Y				
Todd River Basin																	
Todd							H						H,T?				
Western Plateau Drainage Division																	
Elkedra (Barkly)									Y				Y				
Frew (Barkly)				Y			Y		A	Y		Y	Y				
Gosse (Barkly)										Y			Y				
Kurundi (Barkly)										Y			Y				
Whistleduck (Barkly)		Y		Y			Y		A	Y		Y	Y	A			Y
Dashwood (Burt)													Y				
Day (Burt)													Y				
Napperby (Burt)													Y				
Bonney (Wiso)										H		H	Y				
Hanson (Wiso)													T				
Lander (Wiso)													T				
McClaren (Wiso)													Y				
Murray/Ski (Wiso)													Y				
Wycliffe													T?				
No. Of Drainages	1	4	1	2	1	1	5	1	?	6	2	4	19	?	?	1	4

Y = recent record; H = Historical record; T = Translocation/introduced; T? = Possibly translocated; A = anecdotal record; A? = anecdotal record - species not specified; Q = unconfirmed

10.8 Fish Species Assemblages of Individual Drainage Systems

The distribution of species is presented by drainage system. Drainages are presented in order of the number of species. This is a level of detail greater than previously summarised for the whole study area and incorporates new species for some drainage systems based on this survey. Reports of the absence of fish from some drainage systems are also presented.

Fish of the Georgina River System

In total, 11 native species are known from the Georgina River system (Wager & Unmack 2000), of which 10 are confirmed as occurring in the NT by museum specimen records.

Table 21. Native fish of the Georgina River system

<i>Ambassis sp. (central Australia)</i>	Glassfish, Northwest Glassfish	
<i>Nematalosa erebi</i>	Bony Bream	
<i>Glossogobius aureus</i>	Golden Goby	possible taxonomic uncertainty
<i>Melanotaenia splendida subsp. tatei</i>	Desert Rainbowfish	
<i>Macquaria sp. (Lake Eyre)</i>	Lake Eyre Golden Perch, Yellowbelly	
<i>Neosilurus hyrtlui</i>	Hytrl's Catfish	
<i>Porochilus argenteus</i>	Silver Tandan or Catfish	
<i>Amniataba percoides</i>	Banded Grunter	
<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	
<i>Bidyanus welchi</i>	Welch's Grunter	not confirmed in NT section
<i>Scortum barcoo</i>	Barcoo Grunter, Black Bream	

The Georgina River system can be divided into several geographic sub-sections with respect to fish habitat.

The Barkly Tableland section of the Georgina system is defined here as up stream of Lake Nash Waterhole. The catchment is predominantly within the undulating plains known as tablelands and extends to the north of the arid NT. Two major tributaries are included, the Rankin and James rivers, and there are several other smaller tributaries. Museum records indicate the presence of all species but *B. welchi* in the Barkly Tableland section. We caught five species: *Ambassis sp.*, *N. erebi*, *M. splendida subsp. tatei*, *P. argenteus* and *L. unicolor*. Many specimens from sampling by Hamar Midgley and Henry Nix are not yet accessioned into museum database records (H. Nix pers. comm.).

To the south of Lake Nash Waterhole there are various tributaries that commence in the NT in terrain of generally low relief, and cross the Queensland border before joining the Georgina River. These include the Milne River, Woodroffe River, Imborditure Creek and Manners Creek. They are distinguished by a lack of long-term waterholes. Several species have been caught from temporary waterholes on the Woodroffe River. At Eldita Waterhole we caught *N. erebi* and *P. argenteus*, and there is an earlier record of *L. unicolor* from upstream. It is presumed that the temporary waterholes of this area are intermittently colonised by many of the species that occur in the Barkly Tableland section.

Six species were recorded by Fogarty *et al.* (1995) from a long-term and possibly permanent waterhole on Pettigrew Creek on the east side of the Toko Ranges (possibly Nora Waterhole): *Ambassis sp.*, *N. erebi*, *M. splendida subsp. tatei*, *N. hyrtlui*, *A. percoides* and *L. unicolor*. The identification of *N. hyrtlui* was unconfirmed when the report was written. A specimen was apparently sent to the NT Museum, but there is no corresponding record in data obtained from the Museum in 2000. The habitat was consistent with other records of *N. hyrtlui* (clear water), but the fish in question could have been *P. argenteus*.

Wager and Unmack (2000) report that the exotic pest species *Gambusia holbrooki* (Mosquito fish) is spreading in the Diamantina River, and it must be assumed that it will eventually populate the Georgina.

The Field River is a potential tributary of the Georgina system but is not included here because there is no substantiated surface water connection.

Sandover Section of Georgina River System

The Sandover River System is treated as a distinct subsection of the Georgina River since it may not connect to the Georgina for decades at a time. Surface water connection has been confirmed by analysis of satellite images from 2000 and 2001.

There are five species known from the Sandover River system.

Table 22. Native fish of the Sandover River system

<i>Ambassis sp. (central Australia)</i>	Glassfish, Northwest Glassfish	Ooratippra & Arapunga creeks (Dulcie Ranges). Previously determined as <i>A. mulleri</i> .
<i>Melanotaenia splendida subsp. tatei</i>	Desert Rainbowfish	Ooratippra & Arapunga creeks (Dulcie Ranges)
<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	Ooratippra & Arapunga creeks (Dulcie Ranges)
<i>Nematalosa erebi</i>	Bony Bream	Junction Waterhole (junction of Sandover and Bunday Rivers)
<i>Porochilus argenteus</i>	Silver Tandan or Catfish	Argadargada Waterhole in 2 nd Sandover Floodout, plus an anecdotal record from Waite River homestead attributed here to this species but may have been <i>Neosilurus hyrtlii</i> .

Three species have been caught in the long-term waterholes of Ooratippra Creek in the Dulcie Ranges by each of three surveys (Latz & Langford 1983; Gibson *et al.* 1989; wetlands survey 2001): *Ambassis sp.*, *M. splendida subsp. tatei*, and *L. unicolor*. We also caught *L. unicolor* in the Dulcie Ranges catchment of the Bunday River at Elkira Springs (Alkara Creek). We caught two additional species in lower reaches of the Sandover in 2001: *N. erebi* in Junction Waterhole at the confluence of the Bunday and Sandover rivers and *P. argenteus* in Argadargada Waterhole.

The Dulcie Ranges waterholes have not been systematically surveyed and may be a refuge for all five species and possibly others. However, it is likely that *N. erebi* and *P. argenteus* were only recent migrants from the Georgina River, to which the Sandover connected in January 2001 (based on interpretation of satellite imagery). If so, they may not have colonised the Ooratippra catchment. An anecdotal record of a catfish in the Waite River section of the Sandover River system, from the very wet period in the mid 1970's, is likely to have been *P. argenteus*, but may have been *Neosilurus hyrtlii*.

Further survey work is required in the Dulcie Ranges and should target possible additional species with night fishing; for example *Neosilurus hyrtlii* and *Mogurnda* species.

Fish of the Finke River System

There are nine native species (and no introduced species) known from the Finke River system. The fishes of the Finke River have attracted interest from the times of early exploration by non-aboriginal people, and are relatively well represented by specimens in museums. The change in number of species listed for the Finke River between Glover's 1982 list (18 possible species); Davis's 1995 list (11 species) and the 2000 list of Wager and Unmack (9 species) is more indicative of the leaps forward in taxonomy than survey work.

Five subsections of the Finke River system are defined here for describing the distribution of fishes: the Palmer River; the 'Upper Finke' (all tributaries upstream of McMinn Creek junction which is south of Running Waters); the Hugh River and tributaries; the mid Finke from McMinn Creek junction to Horseshoe Bend, including minor tributaries; and the lower Finke River and associated tributaries.

Table 23. Native fish of the Finke River system

<i>Ambassis sp. (central Australia)</i>	Glassfish	upper and mid Finke
<i>Craterocephalus centralis</i>	Finke Hardyhead	upper and mid Finke; Hugh
<i>Nematalosa erebi</i>	Bony Bream	upper and mid Finke; Hugh
<i>Mogurnda larapintae</i>	Finke Mogurnda or Gudgeon	upper Finke; Palmer
<i>Chlamydogobius japaipa</i>	Finke Goby	upper and mid Finke
<i>Melanotaenia splendida subsp. tatei</i>	Desert Rainbowfish	widespread: caught in floodout and Hugh R. (this survey)
<i>Neosilurus hyrtlil</i>	Hytrl's Catfish	upper Finke; Hugh
<i>Amniataba percooides</i>	Banded Grunter	upper and mid Finke; Hugh
<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	widespread

The confirmed distribution of species within the Finke system are summarised in the third column.

Various authors, most recently Allen *et al.* (2002) state that *Chlamydogobius japaipa* is restricted to the upper Finke River; however, several records extend its range to the mid Finke near Horseshoe Bend station homestead. It is likely that the previous underestimates of the extent are an artifact of relatively little systematic sampling, mostly carried out in dry times, and the fact that the species is relatively cryptic.

Fish of unknown type were observed in Lake Pulcura, in the Karinga lakes system, in 1989, when the lake was drying and becoming more saline (A. Stanes pers. comm.). These fish may have been introduced, unknown to the landholder (J. Stanes pers. comm.), or may have migrated from the Finke River. The lake is probably connected to Karinga Creek by surface water during flood peaks, and Karinga Creek connects to the Finke River, although the channel is not shown as connecting on 1:250,000 topographic maps. The current boundary of the Finke Basin and Lake Eyre Drainage Division do not incorporate the Karinga Creek catchment but should be amended to do so (as detailed in chapter 4). Fish have not been recorded in Lake Pulcura in other inundations, including the most recent in 2000 (J. Stanes pers. comm.). The fish were described as long and thin and could possibly have been Hardyhead (*Craterocephalus centralis*).

Limited sampling at Charlotte Waters and the Snake Creek floodout in 2001 and some museum records confirm two species for the lower Finke and floodout area: *Leiopotherapon unicolor* and *Melanotaenia splendida subsp. tatei*. However, it is likely that several if not all of the other species also occur following floods.

An exotic species, *Perca fluviatilis* (Redfin), was apparently introduced to the mid-Finke in the 1950's (M.Lines pers. comm.) but does not seem to have persisted.

Further survey work is required to determine the distribution of the various species in the various subsections of the river system, particularly in the Palmer River and Hugh River headwaters.

Fish of Whistleduck Creek System

There are seven naturally occurring species known in Whistleduck Creek.

Table 24. Naturally occurring fish of the Whistleduck Creek system.

<i>Ambassis sp. (central Australia)</i>	Glassfish	recorded by Bishop & Larson (1983) as <i>A. agrammus</i>
<i>Nematalosa erebi</i>	Bony Bream	
<i>Mogurnda sp. (Davenport Ranges)</i>	Davenport Ranges Mogurnda or Gudgeon	recorded by Bishop & Larson (1983) as <i>M. mogurnda</i> and assumed here to be the same taxonomic entity as the Gudgeons in the Frew.
<i>Melanotaenia splendida subsp. tatei</i>	Desert Rainbowfish	
<i>Neosilurus hyrtlilii</i>	Hytrl's Catfish	
<i>Amniataba percoides</i>	Banded Grunter	
<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	

Whistleduck Creek runs north from the Davenport Ranges and includes several permanent waterholes and rockholes in the ranges, as does its main tributary, Blackfellow Creek.

Bishop and Larson (1983) report capture of all seven species in 1983 and note that previously four species were known from a survey by Latz and Howe in 1970: *Ambassis sp.*, *N. erebi*, *M. splendida subsp. tatei*, and *L. unicolor*.

We caught four species at night using a cast net: *Ambassis sp.*, *M. splendida subsp. tatei*, *N. hyrtlilii* and *L. unicolor*. Unfortunately, no frozen specimens of *Mogurnda*, suitable for genetic analysis of its taxonomic status, were obtained from Whistleduck Creek during our survey.

In addition to the seven native species, it is believed that one or more species native to the Murray-Darling river system have been introduced to the Whistleduck system, as discussed in the section on introduced fishes. There have probably been at least two introductions of *Macquaria* species (Golden Perch) to Whistleduck Creek, at least one of which may have been from Cooper Creek stock (P. Saint pers. comm.) and thus may have been *Macquaria sp. (Lake Eyre)* rather than *Macquaria ambigua*. Apparently they are still present. Wager and Unmack (2000) report the introduction of another species that is not indigenous to the NT: *Bidyanus bidyanus* (Silver Perch), a native of the Murray-Darling drainage system.

Fish of the Frew River System

There are five naturally occurring species known in the Frew River.

Table 25. Naturally occurring fish of the Frew River system.

<i>Mogurnda sp. (Davenport Ranges)</i>	Davenport Ranges Mogurnda or Gudgeon	previously recorded as <i>M. mogurnda</i>
<i>Melanotaenia splendida subsp. tatei</i>	Desert Rainbowfish	
<i>Neosilurus hyrtlilii</i>	Hytrl's Catfish	
<i>Amniataba percoides</i>	Banded Grunter	
<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	

The Frew River runs north from the Davenport Ranges and includes several large permanent waterholes and rockholes in the ranges and some large waterholes in the alluvial plains to the north. Hatches Creek and Lennee Creek are the main tributaries. The Frew connects to Teatree Creek at their floodouts, but nothing is known of fishes in Teatree Creek.

Latz and Howe caught four species in the Frew drainage system in 1970 (reported in Bishop & Moses 1983), being every species but *N. hyrtlii*, which was added to the list known for the drainage by Bishop and Larson (1983).

In 2001 we caught all five species in the upper catchment of the Frew River. We also caught three species from the main floodout swamp of the Frew, which can hold water for well over six months after filling: *Mogurnda sp.*, *M. splendida subsp. tatei* and *A. percoides*.

In addition to the five native species listed above, it is believed that one or more species native to the Murray-Darling river system have been introduced to the Frew. A cattle station owner interviewed in this survey, referred to fish he had caught in Hatches Creek on the Frew River as Cod. These may have been *Maccullochella peelii* (Murray Cod) or a species of *Macquaria* (Golden Perch). It is not known whether species introduced to the Frew have formed self sustaining populations.

Fish of Kurundi Creek

Kurundi Creek drains north from the Davenport Ranges and is linked with Mosquito Creek at their floodouts.

Table 26. Native fish of Kurundi Creek.

<i>Neosilurus hyrtlii</i>	Hytrl's Catfish	
<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	

Only Kurundi Creek has been sampled. Bishop and Larson (1983) caught only *L. unicolor*. In 2001 we caught both *L. unicolor* and *N. hyrtlii*.

Fish of Gosse River

Gosse River drains north from the Murchison Ranges.

Table 27. Native fish of Gosse River.

<i>Neosilurus hyrtlii</i>	Hytrl's Catfish	
<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	

Bishop and Larson (1983) record information supplied by local Aborigines that indicated that the Gosse River had been devoid of fishes but had then been colonised about five years prior to their survey, in which they caught both species.

Fish of Bonney Creek

Table 28. Native fish of Bonney Creek.

<i>Leiopotherapon unicolor</i>	Spangled Grunter or Perch	
<i>Neosilurus hyrtlii</i>	Hytrl's Catfish	historical record from 1898
<i>Amniataba percoides</i>	Banded Grunter	historical record from 1898

There are numerous waterholes marked on 1:250,000 scale topographic map but no information on permanency.

Bishop and Larson (1983) only caught *L. unicolor* in their survey but cited a historical reference (Davidson 1904: Central Australian Exploration Syndicate) from observations in 1898 clearly matching *Neosilurus hyrtlii* and *Amniataba percoides*. Johnson *et al.* (1983) report that the 1898 observations were by Alan Davidson while looking for gold and that the report was to the South Australian Parliament. Apparently, the three species were observed at 'Old Station Waterhold'.

Drainages with a single indigenous fish: *Leiopotherapon unicolor* (Spangled Grunter)

Leiopotherapon unicolor (Spangled Grunter) is by far the most widespread of the arid NT species. There are several drainages where it is the only naturally occurring species and some where it has been translocated from other arid NT drainages. Information about the abundance and longevity of waterholes and migration opportunities is included in table 29 below, to assist with establishing the reliance of *L. unicolor* on permanent water and the likelihood of other species being present.

Table 29. Drainages with a single indigenous fish: *Leiopotherapon unicolor* (Spangled Grunter).

Lake Eyre Drainage Division:
Todd River (Todd River Basin) <i>L. unicolor</i> was abundant in 2000-2002. It is likely that the present population results from either translocation or migration across watersheds several decades ago, since there were no fish there in the 1950s (P.Latz pers. comm.), and no fish were recorded by the Horn Expedition. Artificial ponds in the Alice Springs Golf Course may be one of the drought refuges that now allow <i>L. unicolor</i> to persist in the Todd River system, to which they connect during heavy rains (R.Henderson pers. comm.). There are some long lasting but non-permanent waterholes in the Todd River system including: Wiggleys Waterhole on the upper Todd, Simpsons Gap on Roe Creek; John Hayes Rockhole on a tributary of Trephina Creek; Bitter Springs on Bitter Springs Creek; several pools on the Ross River; Paddy's Rockhole on a tributary of Giles/Atnarpa Creek; and Chabanna Waterhole on Atnarpa Creek. A waterhole is sometimes scoured out and inundated by floods in Trephina Gorge, and may last several years subsequently, but may also be dry, or filled with sand for many years. Unmack (2001a) notes that <i>Melanotaenia splendida subsp. tatei</i> (Desert Rainbowfish) have been recorded in the Todd by Glover in 1979, but subsequent searching has not relocated the species. Unmack (2001a) reports that several exotic species have been recorded from the Todd but are not extant.
Plenty and Hay Rivers (joined) (Hay River Basin) Various museum and survey records indicate a persistent population of <i>L. unicolor</i> since 1978. There are permanent or semi-permanent waterholes in the Dulcie Ranges on: Yam, Oorabra and Oomoolmilla Creeks. Peter Latz (pers. comm.) believes that fish may have been introduced to this system by non-aboriginal people.
Field River (Georgina Basin) Fish were reported by Graham McDermot (lessee of Tobermorey Station) and are assumed to be <i>L. unicolor</i> . The main tributary is Marqua Creek. There are no known permanent waterholes but two large dams are permanent, being spring fed. Connection of the Field to the Georgina in large floods is possible but undocumented.
The Barkly Basin (Western Plateau Drainage Division):
Elkedra River (Barkly Basin) Flows east towards the Georgina River but may be isolated from it by pervious limestones as well as the current lack of flow volumes. There are several permanent and near permanent waterholes. There is anecdotal evidence that a species of <i>Macquaria</i> , possibly <i>M. ambigua subsp. ambigua</i> (Golden Perch, Yellowbelly) has been introduced to the Elkedra River and is persisting. Latz and Howe caught <i>L. unicolor</i> in the Elkedra River in 1970, but Bishop and Larson did not in 1983. Large numbers were observed in the 2001 survey for the arid NT wetlands inventory. Johnson <i>et al.</i> (1983) report 1898 observations by Alan Davidson that his party feasted on fish from the Elkedra River.
Drainages flowing west from the Davenport and Murchison ranges (Wiso Basin, Western Plateau Drainage Division):
McClaren Creek (Wiso Basin) <i>L. unicolor</i> was recorded by Bishop and Larson (1983). There is one waterhole marked on the 1:250,000 scale topographic map but no information on permanency.
Wycliffe Creek (Wiso Basin) <i>L. unicolor</i> was abundant in residual waterholes in 2001. There is at least one permanent or semi-permanent waterhole near the Davenport Range (D.Debney pers. comm.) and a large long lasting/permanent in-channel dam at the Stuart Highway (Wycliffe Waterhole). Numerous waterholes marked on 1:250,000 scale topographic map in the upper catchment are reported to be shallow and not long lasting (D.Debney pers. comm.). Fish (unknown species) were introduced in 1989 (D.Debney pers. comm.)
Murray Creek (Wiso Basin) <i>L. unicolor</i> was abundant in residual waterholes in 2001. There are numerous waterholes marked on 1:250,000 scale topographic map. A large lowland waterhole at Murray Downs homestead is believed to be long lasting (based on comments by Sean Leigh). Murray Creek joins Skinner Creek prior to a combined terminal floodout at Warrabri Swamp, where water lasts for over six months after filling (based on comments by Robert Paul).
Skinner Creek (Wiso Basin) It is presumed that <i>L. unicolor</i> is present in Skinner Creek as it joins Murray Creek at the floodout. Numerous waterholes are marked on the 1:250,000 scale topographic map, but there is no documentation of permanency. Further survey is suggested for this creek as it may harbour additional species for the Western Drainage Division.

Drainages flowing north to the Tanami Desert (Wiso Basin, Western Plateau Drainage Division):
Hanson River (Wiso Basin) <i>L. unicolor</i> was translocated to this river; probably with fish originating from Napperby Creek. There are no natural permanent waters, but a number of dams now allow the species to persist. On Pine Hill Station, spring fed pools may last for years but are not permanent (G.Bowman pers. comm.). The dam in a natural claypan near Claypan Bore is kept permanently inundated by pumping from the bore. <i>L. unicolor</i> and also Golden Perch and Silver Perch were introduced to Mount Esther Dam on Anningie Station in the 1980s, and the dam has not been dry since (M.Lines pers. comm.). The dam probably connects to the Hanson River at times, but it is unlikely that either Golden Perch or Silver Perch persist in the Hanson River due to the lack of appropriate habitat. These two introduced species are assumed to have been <i>Macquaria sp.</i> and <i>Bidyanus bidyanus</i> respectively.
Lander River (Wiso Basin) <i>L. unicolor</i> was translocated to this river via Mount Allan Dam, with fish originating from Napperby Creek (M.Lines pers. comm.). There are no natural permanent waters but various long lasting waterholes occur, including in the floodout channels to the south of Lake Surprise. There are also various long lasting springs, at least one of which, on Spring Creek, is reputed to be a permanent source of drinking water from the seepage area, even when not flowing sufficiently to inundate any pools (M.Lines pers. comm.). A number of dams also contribute to the persistence of <i>L. unicolor</i> now it has been introduced, and the species was widespread following heavy rains in the catchment in February and April 2000 and March 2001, including the Mount Allan area. White Dam is one of those that is virtually permanent (M.Lines pers. comm.)
Drainages flowing into or towards Lake Lewis (Burt Basin, Western Plateau Drainage Division):
Day Creek (Burt Basin) The first specimens of <i>L. unicolor</i> were collected from Day Creek in 1970 by Latz and Howe. There is a series of rockholes with the upper and lower ones marked on the 1:250,000 scale topographic maps as North Twenty Mile and South Twenty Mile Waterholes. North Twenty Mile is considered to be the longest lasting and may be permanent (M.Lines pers. comm.). Although quite small, it is deep and well shaded. Day Creek is not mapped as having channels connecting to Lake Lewis on the 1:250,000 scale topographic map, but in large flood events surface waters do connect it to the lake (M.Lines pers. comm.) and are evident from satellite imagery as shown in appendix 2.
Napperby Creek (Burt Basin) Prior to the 1974 floods there were no fish in Napperby Creek, but it was colonised via Lake Lewis in 1974 (M.Lines pers. comm.). Fish persist in rockholes in the upper catchment, the longest lasting of which is Beantree Waterhole. Beantree Waterhole dried up on the surface in the local drought of 1994-96 (R.Chisholm pers. comm.). In 2001 fish were present, perhaps having recolonised via Lake Lewis when it was inundated by the floods of 2000.
Dashwood Creek (Burt Basin) <i>L. unicolor</i> was collected from a large Lignum swamp connected to Dashwood Creek in 2001. Although the swamp has a dam excavated in the centre, the dam dries up completely. The fish almost certainly originated from Lake Lewis in 2000.
The Derwent (Burt Basin) The landholder reported an absence of fishes (I.Morton pers. comm.). However, a probable surface water connection to Lake Lewis in February 2000 was evident from satellite imagery, so sporadic occurrence of <i>L. unicolor</i> is likely. There are several marked waterholes on The Derwent, but their size and longevity are not recorded.
Gidyea Creek (Burt Basin) There is no record of fish. However, a probable surface water connection to the western end of Lake Lewis in February 2000 was evident from satellite imagery, so sporadic occurrence of <i>L. unicolor</i> is likely.

Drainages With No Fish Records

There is reasonable evidence that there are no fish in the drainage systems listed in the following table.

Table 30. Drainages with no fish

Hale River (Todd River Basin) Gibson <i>et al.</i> (1992) reported an absence of fish in waterholes they surveyed on the Hale River.
Gastralobium Creek (Barkly Basin) The large long lasting waterholes such as Gastralobium Waterhole are all known to dry up, and no fish have ever been observed there over several decades (R.Driver pers. comm.).
All drainages in the Mackay Basin and Warburton Basin are believed to be devoid of fish.

In three basins with fish populations there are several drainages for which there is insufficient information to confirm the suspected absence of fish. These are listed in the following table. For some, there is a possibility that *L. unicolor* may occur, at least sporadically, given its wide spread distribution and exceptional dispersal abilities.

Table 31. Drainages with an unconfirmed absence of fish

Illogwa Creek (Todd River Basin)
Lucy Creek (Georgina Basin)
Taylor Creek (Wiso Basin)
Edinburgh Creek (Wiso Basin)
Wauchope Creek (Wiso Basin)

Around the South Australian border, south east of Kulgera, some of the minor creeks do connect to Lake Eyre via Hamilton Creek and the Macumba River. There are no known long-term waterholes in these creeks and no record of fishes, but it is possible that species of fish from the Lake Eyre system could occur there during prolonged wet periods. The most likely is *Porochilus argenteus*, which Wager and Unmack (2000) list for the Macumba basin and which has strong migration abilities. Other species known from the Lake Eyre catchment may also sporadically occur in NT tributaries, including *Craterocephalus eyresii* and *Chlamydogobius eremius*.

10.9 Environmental Tolerances, Behavioural and Dispersal Characteristics of Native Arid NT Species

Environmental Tolerances of Arid NT Fishes

Fishes of arid Australia utilise aquatic environments with physical attributes that are marginal for fish habitation, such as high temperature and low oxygen (Glover 1990). Information on environmental tolerances of arid NT fish species is scattered through the literature (including Glover 1979; Glover 1982; Llewellyn 1973); however, it is predominantly from studies of populations outside of the arid NT. Glover (1990) gives a summary of behavioural and physiological adaptations of central Australian fishes as does Peter Unmack in his internet site (internet site of Australian Desert Fishes Pages). Values of pH and conductivity recorded in waterbodies where fish were caught in our survey are listed in Volume 2 of this report.

Several arid NT species can tolerate quite high salinities. We recorded *Leiopotherapon unicolor* (Spangled Grunter) thriving in water with a conductivity of 32,000 μ S/cm in Lake Lewis in September 2000 (c.f. sea water c. 51,500 μ S/cm). Other species are known to tolerate moderately saline waters. We recorded seven species in reaches of the mid and lower Finke River, in water with conductivity exceeding 4,000 μ S/cm. Three of these species were in water at 4,700 μ S/cm, which is at the internationally accepted upper limit for freshwater (Wager & Jackson 1993). As noted by Wager and Jackson (1993) the term 'freshwater fish' is not appropriate for many inland species. Virtually none of the naturally occurring fishes of the arid NT has any marine distribution. The only exception is *Glossogobius aureus* (Golden Goby), which has a marine larval stage in coastal populations (Allen *et al.* 2002).

There is no firm evidence of an ability in *L. unicolor* to survive extended periods without surface water. The species certainly has a relatively good ability to survive out of the water for short periods. For example, Llewellyn (1973) reported that a fish had jumped out of a tank and had become quite dry on one side and appeared dead, but revived when re-immersed. Williams in *Life in Inland Waters* (1983) records that some species of galaxiid burrow in damp soil to survive dry periods and that *L. unicolor* may do the same, also noting claims that 'Aborigines used to collect the species from dried mud' (p.72). Glover (1990) states that *Chlamydogobius eremius* and possibly *L. unicolor* 'can survive at least for short periods buried in wet or moist mud' (p.193). However, there is no evidence of physiological dormancy, called aestivation, to survive dry periods. Fish that have burrowed into wet mud to survive will die if the mud dries out (Glover 1990). Llewellyn (1973) made systematic but unsuccessful attempts to induce aestivation in *L. unicolor*, by allowing water to slowly dry out of containers with fish and substantial

layers of mud. The term aestivation is used here in a broad sense to refer to dormancy during a dry time. In the strict sense, aestivation refers to summer dormancy.

Reports of dead fishes, often called fish kills, are common and most frequently involve *Nematalosa erebi* (Bony Bream). There are many reports of fish deaths at Ormiston Gorge, including *L. unicolor* and *Neosilurus hyrtlui* as well as *N. erebi* (R. Henderson pers. comm.). Extensive deaths of fishes in the Georgina River were reported by pastoralists during the 2001 wetlands survey and directly observed in a waterhole on the lower Hugh River. There may be a variety of contributing causes including a reversal of thermal layering (stratification) of waterholes in winter, when very low air temperatures cool surface waters which then mix with deoxygenated water that was previously confined to colder lower levels in the water body (S. Reilly pers. comm.; Davis & Froend 1998). Larger fish may be more susceptible due to a lower ratio of gill surface area to body mass (R. Henderson pers. comm.). Some fish may also be killed by the low temperature of the water (Davis & Froend 1998). Langdon *et al.* (1985) found a parasitic infection of the gills to be the cause of death in *N. erebi* in waterholes of the upper Finke River in winter 1984, in association with low water temperatures. Deaths of *N. erebi* in the Murray River involved *Achlya*, a parasitic fungus (Puckridge *et al.* 1989 cited in the internet site of Australian Desert Fishes Pages).

Observations on Distribution and Behaviour with respect to Dispersal Abilities

Various observations on the behaviour and dispersal of the naturally occurring fishes of the arid NT are made below. Many of the observations pertain to the somewhat enigmatic dispersal and survival abilities of *Leiopotherapon unicolor*.

The exceptional dispersal abilities of *L. unicolor*, such as swimming rapidly in very shallow water, are recorded by several authors (e.g. Unmack 2001a; Wager & Unmack 2000; Lake 1978). Various stories of *L. unicolor* turning up in surprising places were heard from landholders during this survey. They include occurrence in a dam that had never been stocked and is not built across a drainage line. Also, we caught fish in two water bodies where the landholders thought there were none. There are various reports of rains of fishes involving *L. unicolor* (e.g. Wager and Unmack 2000), and we encountered one such story of fish appearing in the street gutters on a hill in a Queensland town. Lake (1978) was of the opinion that the species can colonise isolated dams via temporary surface water connection to creek lines during heavy rain, and Bishop and Moses (1983) suggest that *L. unicolor* may be able to cross watersheds between the upper reaches of adjacent drainage systems during heavy rainfalls. There is anecdotal evidence of impressive jumping abilities in *L. unicolor* in the order of 1 to 2 metres at Aranju Waterhole on the Elkedra River (R. Driver pers. comm.). The exceptional ability of *L. unicolor* to swim in shallow water may explain most but perhaps not all sudden appearances of fish (Wager and Unmack 2000). Glover (1990) and Unmack (2001b) conclude that it is possible for fish species to be dispersed through the air, either as fish or eggs via thermal air movement or birds, but that such occurrences must be very rare.

Two landholders reported to us the appearance of *L. unicolor* in creeks following rain, prior to any apparent re-connection to ongoing waterholes: Roy Driver of Elkedra Station (Elkedra River) and Graham McDermot of Tobermorey Station (Gumhole on Gumhole Creek in the Toko Ranges).

The specimens of *L. unicolor* caught in the Dashwood Creek system are presumed to be a result of recent migration from Lake Lewis, since there are no documented permanent waterbodies in the catchment. Flood waters of Dashwood Creek almost certainly connected to Lake Lewis in February 2000 (based on interpretation of satellite data from 1 March 2000). The creek also reached the lake in 1974 (C. Connellan pers. comm.). Although there are no waterholes marked on the map there are several long lasting springs in the catchment (D. Simms pers. comm.). A record of the aquatic plant *Potamogeton tricarinatus* in the upper catchment may indicate long-term pools in which fish may have persisted since 1974. However, it seems improbable that fish were present in the system for 26 years without being observed.

Bishop and Larson (1983) noted that in Blackfellow Creek, a tributary of Whistleduck Creek, *Mogurnda sp.* was observed in pools above migration obstacles to *L. unicolor*, which is indicative of the ability of *Mogurnda spp.* to climb. We only caught *Mogurnda spp.* in pools mixed with other species, including a large swamp in the floodout of the Frew River. Live *Mogurnda larapintae* specimens held in

a fish tank in 2002 were observed climbing the tank walls and staying out of the water for extended periods (> 5 minutes) and some were found dead, having presumably climbed out of the tank and then desiccated or asphyxiated.

Bishop and Larson (1983) record information supplied by local Aborigines that indicated that the Gosse River, in the Murchison Ranges, had been devoid of fishes but had then been colonised about five years prior to their survey, in which they caught both *L. unicolor* and *Neosilurus hyrtlii*. Bishop and Larson (1983) only caught *L. unicolor* in their survey of Bonney Creek. However, they cite a historical reference that indicates both *N. hyrtlii* and *Amniataba percoides* were present in Bonney Creek in 1898. Although all specimen records from drainages running west from the Davenports are of *L. unicolor*, the historical reference indicates that other species were present and their abundance in Bonney Creek has since either dropped greatly or they have died out (Bishop & Larson 1983). It is certain that the abundance of most species fluctuates widely in temporary streams. For example, Latz and Howe caught *L. unicolor* in the Elkedra River in 1970, but Bishop and Larson did not in 1983. Large numbers were observed in the 2001 survey for the arid NT wetlands inventory, including thousands in the terminal floodway of the Elkedra river as it runs out into the sandplain on Annitowa Station.

Little is documented about the dispersal abilities of *Neosilurus hyrtlii*. *N. hyrtlii* was caught at Kurundi Creek in our survey but not by Bishop and Moses (1983) who fished the creek far more extensively. It is possible that this species was not present in the Kurundi Creek catchment in 1983 and has since colonised or been translocated from elsewhere. The Kurundi Creek joins to Mosquito Creek at their mutual floodout. Mosquito Creek appears to have never been scientifically sampled for fish, and we have not encountered written documentation of the longevity of waterholes in its catchment. However, in our experience, *N. hyrtlii* is relatively cryptic in larger waterbodies (Finke River and Whistleduck Creek) but schools at night, an observation also made by Unmack (2001a). Thus, if Bishop and Larson (1983) did not sample at night they may have missed the species even though it was present. In several small clear, shallow waterholes of the Frew River, we observed *N. hyrtlii* by day, in the vicinity of cover such as underwater rock overhangs.

Bishop and Larson (1983) hypothesized that fish species may be eliminated from and subsequently recolonise catchments in the Davenport and Murchison Ranges, with droughts favouring the hardiest and most aggressive species – *L. unicolor* – and heavy rains favouring recolonisation by the less hardy species which persist in the most favourable catchments. They rank species according to migratory ability as follows (7 = best migration ability): *L. unicolor* (7), *Mogurnda sp.* (6), *M. splendida subsp. tatei* (5), *N. hyrtlii* (4), *A. percoides* (3), *Ambassis sp.* (2), *N. erebi* (1).

Our records of *P. argenteus* and *N. erebi* in lower reaches of the Sandover River are probably indicative of their dispersal abilities. It seems likely that both species had migrated from the Georgina River in January 2001: about 15–20 km in the case of *P. argenteus*, caught at Argadargada Waterhole; and 150 km in the case of *N. erebi*, at the junction of the Sandover and Bunday rivers.

Davis (1995) states that the Finke Hardyhead (*Craterocephalus centralis*) appear to be restricted to pools in the upper reaches of the Finke River system, however in this survey they were caught in the mid reaches at Idracowra and Horseshoe Bend stations and museum specimens have been collected from the Hugh River at Maryvale Homestead. Presumably these and other species are aided in their downstream dispersal by high velocity floods such as those in 2000 and 2001.

The fish observed in Lake Pulcura in 1989 may have migrated from the Finke, via Karinga Creek and a series of lakes, although no connecting channels are mapped on the 1:250,000 scale topographic maps. There is no data on the duration of flows of Karinga Creek into the Finke River but they are likely to be short. If the fish observed in Lake Pulcura were from the Finke then this would be an interesting example of their migratory ability, as the direct distance covered is over 100 km. The fish were described as long and thin, which best matches *Craterocephalus centralis* of the Finke River fishes.

10.10 Physical Habitat Characteristics Influencing the Persistence and Diversity of Fishes in Arid NT Drainage Systems

The number and distribution of permanent and other long-term waterholes within drainage systems is a strong influence on the species that occur. Other aspects of the waterholes are also important such as vegetation, depth, substrate, turbidity and salinity. The long-term waterholes are the core habitat for fish. Temporary waterholes, those that are more often dry than wet, may sometimes be reconnected by flowing water before they dry up, but at other times will dry out completely between river flows, with the death of all the fish within them. In the more severe droughts, only the few permanent waterholes provide a refuge. It is theoretically possible for fish to persist in drainage systems with no permanent waterbodies, but with a collection of long-term, non-permanent waterbodies that are sufficiently geographically separated that there is always at least one with water in it (Unmack 2001a). Within the arid NT, this scenario may operate in sections of the Georgina River. In other drainages in the arid NT it is assumed that the presence of indigenous fish is due to one or more of three factors:

- the drainage includes at least one naturally permanent waterbody;
- there is periodic surface water connection to other drainage systems from which fish can recolonise and may persist in long-term but non-permanent waterbodies;
- human translocation of indigenous fish which may persist in natural or artificial semi-permanent water bodies.

Fish dispersal between drainage systems by other natural mechanisms, such as transport of live fish or fertilised eggs by thermal air movements or birds, are considered to be extremely rare (e.g. Glover 1990). Unmack (2001b) discusses possible mechanisms for changing connectivity of drainage systems which may occur through geomorphic processes, in his review of the biogeography of Australian fishes. In the arid NT geomorphic changes in the past tens of thousands of years have typically disrupted the connectivity of drainages rather than causing new connections. These include creation of the Simpson Desert sand dunes, which contribute to the isolation of several rivers from Lake Eyre. The courses of the lower reaches of several major rivers are subject to substantial changes due to low gradients and the consequentially strong influence of sediment deposition by extreme flood events as described by various workers (Pickup *et al.* 1998; Pickup 1991; Patton *et al.* 1993; Bourke 1994, 1998 & 1999). Thus it is possible that drainages may at times be joined to others, such as contemporary channels of the Hay and Plenty Rivers, and the floodouts of the Todd and Hale Rivers (Unmack 2001a), but at other times become isolated. Past fluctuations in rainfall volumes and patterns must also have influenced the connectivity of some rivers in the arid NT, and rivers that have been isolated during the 100-150 years of the historical record may have been joined during extreme floods, within the current climatic regime.

All the drainages with naturally occurring fish populations are thought to have at least one semi-permanent waterhole, and those with natural populations of any fish species additional to *L. unicolor* have a greater number of permanent or long-term waterholes.

Unmack (2001a) examined the relationship between waterhole longevity and the presence of fish in central Australian river systems. This inventory of the arid NT has included collating further information on the longevity of waterholes and springs in the arid NT. There is still considerable scope for collating additional information; a task which Graham Ride is undertaking (pers. comm.). A general observation can be made that the greater the reliability of the aquatic habitat, the more species will be present. For example, six species persist at Dalhousie Springs, in a fairly restricted area, within which the environmental conditions are highly constant due to the thermal springs. Other important influences are the diversity of habitat, including substrate, vegetation and depth.

Permanent and long-term waterholes in drainage systems occur where some combination of hydrology and geomorphology results in long-term net inflow balancing long-term loss. Typically the water is confined by rock or clay resulting in low infiltration rates. Most, if not all, of the permanent waterholes are fed by ground water discharge from rock aquifers. Hyporheic flows in river sands may also be important sources of inflow. However, during prolonged droughts, hyporheic flow probably ceases in most river sections and may only be sustained in places with surface or hyporheic aquifer discharges. Mean annual potential evaporation greatly exceeds rainfall throughout the arid NT, even in exceptionally

wet years, and few waterholes have sufficient inflow from aquifers to match evaporation levels across the landscape. Shading from the surrounding terrain reduces insolation and wind, reducing evaporation significantly for some, but not all, long-term waterholes. Almost all arid NT waterholes drop in level through prolonged droughts, and the permanent ones are typically deep enough that some water remains until the next river flow. A few of the permanent waterholes are only a few metres deep and their longevity is due to the volume and reliability of aquifer discharge.

The depth of some waterholes is highly variable, due to variations in flow patterns and sediment loads. River bed sediments can be highly mobilised during the peaks of large flow events (Barlow 1988) and particularly in waterholes where landform elements promote scouring (Unmack 2001a). Depending on the nature of the flow event, the sediment deposited at a particular waterhole during decreasing flows may be more or less than was present prior to the flow event. In some cases a waterhole may 'disappear' when it is completely infilled with sediment. There is one recorded instance of a semi-permanent waterhole in the upper Finke River, being completely filled by sand and thus effectively 'drying out' with respect to surface water (Redbank Waterhole in 1988). The amount of vegetation cover in the catchment is an important influence (G. Ride pers. comm., P. Latz pers. comm.; Unmack 2001a), such that drought and bushfire can increase both runoff rates and erosion. High run-off in rainfall events following drought probably promotes increased scouring of waterholes, possibly outweighing the influence of increased landscape erosion rates.

On a global scale, all of the arid NT rivers have large variations in flow volumes. Puckridge *et al.* (1998) compared the flow variability of 52 rivers worldwide, identifying measures of variability that are associated with fish biology. Arid NT rivers are not included in the analysis but are assumed here to be amongst the most variable, particularly those in the south of the study area. Rainfall characteristics vary across the study area, as discussed in chapter 1. There is a predominantly north-south gradient, such that rainfall is higher and somewhat more reliable in the northern latitudes. In the northern third of the study area, virtually all the rain falls in summer. This concentration of the rainfall may correspond to generally more intense events and may result in higher runoff rates and stream flows than in the south, where a substantial portion of annual rain may fall in winter. Rainfall may also be relatively uniform across the landscape in the north and patchier in the south, although this is hard to substantiate. All these factors indicate that topographic shelter and aquifer discharge may be less important factors in the permanency of waterholes in the north of the arid NT than in the south.

There are a number of mountain ranges of sufficient elevation to have some orographic effect by precipitating rainfall and potentially a corresponding influence on frequency and volume of stream flow. The limited number of rainfall and stream flow gauging stations makes the importance of this hard to test. The Davenport, Murchison, Dulcie and Toko ranges rarely exceed 200 metres elevation above the surrounding plains and are expected to only exert a weak orographic influence on rainfall. In comparison, parts of the MacDonnell Ranges approach 900 m above the plain and widely exceed 400 m above the plain. The elevated and rocky terrain created by mountain ranges have a more obvious effect on stream flow, such that a high proportion of rainfall collects in drainage channels, both through surface runoff and sub-surface flow. Another important landscape type with high runoff rates is clay plains, particularly the black soil plains that are dominant in the Barkly Tableland (Barkly Basin & upper Georgina River system) and other areas such as parts of the lower Sandover River system and parts of the lower Elkedra River floodplain.

Most records of fishes in the arid NT are from riverine environments, but we also collected specimens from lakes and swamps. Such environments typically have high primary production (photosynthetic) relative to riverine waterholes, and it is not known how important they may be for breeding. Puckridge *et al.* (2000) recorded significant pulses of reproduction in fishes of the Coongie Lakes area in South Australia. No equivalent data are available for the NT, but most large swamp areas that connect to rivers are substantially isolated from long-term riverine waterholes, and should large scale breeding occur, the resulting populations would usually die as a result of the swamps or lakes drying out before new river flows reconnect them to long-term waterholes upstream.

10.11 Drought Refuges and Surface Water Connectivity Within and Between Drainage Systems

The presence and distribution of permanent and some other long-term waterholes are discussed here for some of the arid NT drainage systems with fishes. This is combined with further discussion on the biogeography of some populations and the possibilities for migration of species between some particular river systems.

Lake Eyre Drainage Division

Georgina River System

Of all the arid NT drainages with fish, only the Georgina River is known to regularly connect with other major drainage systems.

The Barkly Tableland section contains numerous large 'near seasonal' waterholes that often dry up and a few deeper long-term and possibly semi-permanent waterholes. The waterholes of this sub-section are all highly turbid from the clays of the surrounding black soil plains. Although there are several very large waterholes, according to Randal (1978) all but one of the Georgina River (including Qld portion) waterholes have dried up at some time since settlement by non-Aboriginal people. Some of the largest and presumably longest-lasting waterholes are One Mile Waterhole at Soudan, Junction Waterhole (junction of Ranken and Georgina) and Big Ranken.

There are no long-term, large, riverine waterholes in the various tributaries that emanate near the Queensland border between Lake Nash Waterhole and the Toko Ranges (e.g. Milne River, Woodroffe River, Imborditure Creek and Manners Creek). The terrain is relatively flat to undulating.

The Toko Ranges on the NT-Queensland border generate several tributaries of the Georgina. Two of these have permanent or semi-permanent spring fed pools in the NT: Alcoora Spring on Alcoora Creek (G. McDermot pers. comm.) and Nora Waterhole (Fogarty *et al.* 1995) up stream of Toko Gorge on Pettigrew Creek. There is some uncertainty regarding naming and location of several waterholes in the Pettigrew Creek area, including Nora Waterhole. A waterhole over the border in Queensland, in Toko Gorge, is also regarded as permanent (Fogarty *et al.* 1995; Blackman & Craven 1996). The Toko ranges waterholes are typically clear and relatively shallow, providing a different aquatic habitat from the other NT sections of the Georgina system.

For distribution purposes the Sandover River system is an important sub-section of the Georgina River system to which it occasionally connects, via Milne River/Bybby Creek. The Sandover River system contains three distinct floodout areas. The upper Sandover River floods out before meeting the Bunday River. Below this we refer to it as the lower Sandover. Ooratippra Creek floods out before joining the lower Sandover and the lower Sandover dissipates across a massive floodout. Surface water connections across all these floodouts have been established from satellite imagery, linking all parts of the catchment to the Georgina River. Within the Sandover River System, the only known long-term (more often wet than dry) waterholes are in the Dulcie Ranges. Several waterholes in the Ooratippra Creek catchment are thought to be permanent and there are some long lasting and possibly permanent small pools in the Dulcie Ranges portion of the Bunday River catchment (Alkara Creek). There are no documented long-term waterholes in the upper Sandover River system (upstream of Junction waterhole).

Finke River System

The Finke River extends for over 400 km with several major tributaries. The permanent and long-term waterholes of the Finke River system are connected every few years except in droughts. Some tributaries, such as Karinga Creek, are connected less frequently, but do not contain long-term fish habitats. The long-term waterholes are all in or close to the mountain ranges of the MacDonnell Ranges bioregion.

The majority of the permanent waterholes are in the Upper Finke; with eight relatively large waterholes: Running Waters, Pucca, Boggy Hole, Glen Helen Waterhole, Two Mile Waterhole, Upper Serpentine Gorge and Ellery Creek Bighole. There is a large variety of size, depth and other geomorphological and hydrogeological characteristics among these. There are various smaller permanent waterholes in the

upper Finke, notably in the Palm Valley area and in the Chewings Range. There are also various other waterholes in the upper Finke that are long-lasting but not permanent. There is one major permanent waterhole (Illara) in the Palmer River catchment and possibly other minor ones upstream of Illara. There is one waterhole in the upper section of the Hugh River catchment that is considered to be at least semi-permanent (at the mouth of Fringe Lily Gorge in the Chewings Range).

Downstream of Running Waters there are several long-term large waterholes in the mid-reaches of the Finke, such as Snake Hole on Henbury Station. The longevities of individual waterholes in this mid-section are poorly documented, but none are considered permanent (P. Latz pers. comm.). There is a similar lack of documentation about the presence and longevity of large waterholes in the mid to lower Hugh River. One in the Mount Burrell area may be relatively long-term. There are no long-term waterholes in the lower sections of the Finke River.

Further work to document the longevity of waterholes in the Finke system is recommended, including further consultation with landholders and written records, including Mabbutt (1971, cited by Bayly 1999) and Strehlow (1948, cited by Bayly 1999).

There is no recorded surface water connection between the Finke River and the Macumba River which flows to Lake Eyre (Unmack 2001a; Williams 1970; Kotwicki 1989). There is also no recorded connection to Dalhousie Springs, which has five endemic species. The generally low relief of the Dalhousie area indicates that surface connection could be possible with the combination of a mega flood in the Finke River and local flooding in the Dalhousie Springs region. However, the evolution of five distinct species at Dalhousie Springs can be attributed to a long period of isolation as well as the distinctive environment of the hot springs.

The Plenty-Hay River System

The Hay River and Plenty River have distinct catchments and terminal floodouts in the Simpson Desert. However, they are connected in their mid reaches by the Marshal River and form a combined drainage system with respect to fish populations.

There are several spring-fed waterholes at the base of the Dulcie Ranges and these are the only natural drought refuge for fishes in the system. A single species, *Leiopotherapon unicolor*, has apparently persisted since the arrival of non-aboriginal people in the area. There are springs marked in the catchments of both the Marshall River and the Hay River (Oomoolmilla and Arthur creeks). The longevity of the refuge waterholes is not well known and while some may be permanent or semi-permanent, there is some doubt whether they are as reliable as those in the Davenport, Murchison and West MacDonnell ranges. If they were of similar reliability, more species might be expected.

It is highly plausible that if they had dried up in the current climate of the past few thousand years, that *L. unicolor* could recolonise from the Sandover River with a combination of sustained above average rainfall, such as in 1974, and heavy local rains where the two river systems almost meet in their upper catchments (less than 1 km apart in flat terrain in the Ongeva Creek – Plenty Dam area).

The Todd River System

The Todd River system has several substantial tributaries each with medium to long-term waterholes, but none of which is known to be permanent. Therefore, it is concluded that the Todd River population of *Leiopotherapon unicolor* is probably a result of migration or translocation in recent decades. Also, there is anecdotal evidence that there were no fishes in the Todd River in the 1950s (P. Latz pers. comm.).

The natural long-lasting drought refuges are: Simpsons Gap and Bond Gap waterholes in the Roe Creek catchment; Wiggleys and Junction waterholes on the Todd River; John Hayes Rockhole and Springs on the South of the Georgina Range in the Ross River catchment; and one or more waterholes in the Giles Creek catchment. The waterhole at Simpsons Gap is known to have dried out. The waterhole at Bond Gap is probably deeper and may be the longest lasting in the system. There are now some 'permanent' artificial waterbodies that connect by surface flow to the Todd River, notably the ponds in the Alice Springs Golf Course. These areas now provide secure drought refuges for *L. unicolor*.

It is possible that *L. unicolor* and possibly *M. splendida* can migrate to the Todd River system from the Finke River system. Possible migration paths include via Lake Lewis and along Sixteen Mile Creek or more directly from tributaries of the Hugh River into tributaries of Roe Creek or Laura Creek. The most likely cross over points from Sixteen Mile Creek to the Todd are on the Burt Plain near Orange Bore and Todd Dam, with distances between channels mapped on 1:100,000 AUSLIG compilation sheets of about 800 m and 600 m respectively. There are various potential cross over points from tributaries of the Hugh River, including one to the west of Pine Gap, where marked channels of the two systems are within 200 m of each other on foot slopes (Alice Springs 5650 1:100,000 topographic map).

The Field River System

There is only anecdotal evidence of fish in the Field River system (G. McDermot pers. comm.). The Field River emanates from the south side of the Toko Ranges and is joined from the north-east by Marqua Creek. It is mapped as dissipating in the Simpson Desert sand dunes to the south-east, and not reaching the Georgina River toward which it heads. As there are no known natural permanent waterbodies in the Field River system, any fish population must presumably be a result of either introduction, translocation or occasional connection to the lower Georgina River to the south-south-east. There are two semi-permanent dams constructed over natural springs in the Field River catchment, within which fish could persist.

Major Drainages in Lake Eyre Basin (NT portion) with No Fishes

The longest drainage without any current fish population is the Hale River (225 km). Unmack (2001a) speculates that the Hale could be episodically colonised by *L. unicolor* from the Todd River by a confluence of exceptional floods in both rivers which flood out into the same area of the Simpson Desert. Subsequently all fish would die out of the Hale in droughts due to a lack of both permanent waters and only a small number of long lasting waterholes.

There are two other substantial drainages in the Lake Eyre Drainage portion of the arid NT which have no records of fish: Illogwa Creek (140 km) and Lucy Creek (60 km). Both have isolated floodouts and well defined watersheds that separate their upper catchments from other drainage systems.

Western Plateau Drainage Division

Within the Western Plateau Drainage Division, there are fish in three of the five basins: the Barkly; the Wiso; and the Burt basins. Those three basins are characterised by a relatively large number of unconnected drainage systems when compared to the Lake Eyre Division portion of the study area. Also, there are less obvious locations for prior connection of most of the drainages of the Barkly and Wiso basins to each other, compared to those of the Lake Eyre Division which all once connected to Lake Eyre.

There is relatively little documentation of the permanency of waterholes in the western Plateau, compared to the Finke River.

Barkly Basin Drainages

The Barkly Basin drainages in the study area all emanate from the Davenport and Murchison ranges, which straddle the watersheds that divide parts of the Barkly, Wiso and Georgina basins. The drainage systems of the Barkly Basin that emanate from the ranges can be usefully grouped as a subsection of the Barkly Basin, referred to here as the Davenport-Murchison Barkly sub-basin. These drainages mostly flow either north or east into an area of sandplain referred to as the Wakaya Desert by Gibson *et al.* (1994). The only exception is the Elkedra River, which flows east towards the Georgina River. The others all currently dissipate and terminate within the Wakaya Desert and do not connect to the major part of the Barkly Basin which is on the Barkly Tableland. Under past wetter climates these drainages are assumed to have connected to the rest of the Barkly Basin drainages on the Barkly Tableland and probably, through the tablelands, to the Georgina River, as recognised by Bishop and Larson (1983).

The relatively high diversity of species in the Davenport-Murchison Barkly sub-basin, compared to the rest of Western Plateau Drainage Division, is due in unknown proportions to the greater number of long-term and permanent waterholes in the ranges and the possibly more recent connection to other drainage divisions via the tablelands. The drainages have been moderately well surveyed (Bishop & Moses 1983; Bishop & Larson 1983), with some additional information from our survey. Their isolation from each other under current climatic and landscape conditions is indicated by the range in numbers of indigenous species within them: Whistleduck Creek system (7); Frew River system (5); Kurundi Creek (2); Gosse River (2); Elkedra River (1).

The Elkedra River has two permanent waterholes of undocumented character and several other large and long lasting waterholes, of which some are semi-permanent (R. Driver pers. comm.).

There are several permanent and long-term waterholes in the Frew River system (e.g. Old Policemans Waterhole and Kangaroo Rockhole) and in the Whistleduck Creek system. But there is insufficient information to estimate the numbers of permanent waterholes in each. There is no mapped connection between the Frew and Whistleduck systems, and they may have been isolated from each other for thousands of years.

Barkly Tableland Portion of the Barkly Basin

Although the Barkly Tableland portion of the Barkly Basin is outside the study area, the connectivity of its drainages are of relevance to the biogeography of fish species within the study area. The tableland portion of the Barkly Basin has very little variation in the elevation of the terrain, and the soils are predominantly 'black soils' clays. As a result of low rainfall infiltration rates and the level terrain, large areas are temporarily inundated during heavy monsoon rains. The drainage network consists of numerous apparently isolated and uncoordinated channels, but which are probably interconnected by the temporary flooding of the 'black soil'.

Within the tableland portion of the Barkly Basin, drainage is internal to the black soil plains, inundating a number of extremely large swamps which are temporary yet quite long lasting (R. Jaensch pers. comm.). It is not documented whether or not there are any permanent waterholes in the 'tableland' section of the Barkly Basin and the fish fauna includes *Scortum barcoo* and *Porochilus argenteus* in addition to those in the Davenport-Murchison sub-basin (based on Larson & Martin 1990 and Unmack 2001b). Some of the deeper riverine waterholes on the tableland may be semi-permanent, and it is possible that there are small permanent or semi-permanent waterholes in gullies and gorges of the Ashburton Range (C. Brock pers. comm.). However, the fish species recorded for the tableland portion of the Barkly Basin all also occur in the Georgina River, and it is highly likely that the tableland drainages occasionally connect by surface water to the headwaters of the Rankin River which is a tributary of the Georgina River.

There may also be occasional surface water connection between the Barkly Basin drainages to drainages of the Gulf of Carpentaria Drainage Division. For example, based on inspection of 1:250,000 scale topographic maps, marked channels of the Barkly Basin (Valhalla Creek) extend within a few hundred metres of those of Kilgour River which is a tributary of the MacArthur River. Likewise, Cresswell Creek of the Barkly Basin extends within a kilometre or so of the headwaters of the Robinson and Nicholson rivers which both drain to the Gulf.

We obtained records of four specimens of fish that have been identified as *Glossogobius aureus* (Golden Goby) from the upper Georgina River. These may be a result of occasional surface water connection to the Gulf of Carpentaria via the Barkly Tableland. According to Wager and Unmack (2000), within the Lake Eyre Basin *G. aureus* is only known from the Georgina River and no other species of Gobiidae has been recorded from the Georgina-Diamantina river system. The species has a wide distribution in countries of the western Pacific Ocean and may have a marine larval stage (Allen *et al.* 2002). However, Wager and Unmack (2000) state that *G. aureus* appears to be common in the Georgina River. If the marine stage is obligatory then the Georgina River population may be a result of recent surface water connection between the ocean and the essentially endorheic (athalassic) Lake Eyre Basin. Alternatively, the Georgina River population may be self sustaining without a marine larval stage and may warrant a separate taxonomic status (species or sub-species). Nevertheless, the Georgina River population could be a relatively recent arrival from coastal populations. A study of the biology of the Georgina River population and genetic investigation and comparison with coastal populations could resolve this issue.

Wiso Basin Drainages

On the west and south-west of the Murchison and Davenport ranges are several drainage systems which are within the Wiso Basin and floodout towards the Tanami Desert. It is likely that some or most of these may have joined in the past and may still do so in exceptional floods. Skinner and Murray Creeks probably reach Wycliffe Creek relatively frequently, and there is anecdotal evidence that the floodwaters of the Taylor can reach those of Wycliffe Creek (D. Debney and K. Bethel pers. comm.). This is corroborated by satellite imagery showing floodwaters of the Taylor extending towards the Wycliffe Creek floodout. The floodout of Wycliffe Creek and several creeks to the north all trend northwards, suggestive of a prior common sink. Bonney Creek is probably joined by Gilbert and McClaren Creek in large floods.

Surveys in recent decades have only recorded *Leiopotherapon unicolor* (Spangled Grunter), but some of the drainages warrant further investigation to check for other species. Also, there are historical records of two other species from Bonney Creek. It is likely that the reliability of the long-term waterholes in the Wiso Basin portion of the Davenport and Murchison Ranges is considerably less than those catchments in the Barkly Basin with multiple fish species. It is possible that they have dried out within the past few thousand years, during which the climate was probably broadly similar to that covered by historical records (past 100 years). This would explain the presence of mainly/only *L. unicolor* which is the hardiest and most able disperser of the region's fishes.

Given the low elevation of the ranges, migration across them cannot be discounted. Also, massive regional flooding on the eastern fringe of the Tanami Desert may have allowed lowland recolonisation from the Barkly Tableland. There is also a possibility that some populations of *L. unicolor* in drainages flowing west from the Davenport and Murchison ranges are a result of human translocation.

There are no naturally occurring fish populations in other parts of the Wiso Basin, but there are self-sustaining populations of *L. unicolor* (Spangled Grunter) in both the Lander and Hanson rivers, as a result of translocation and semi-permanent artificial waterbodies.

Burt Basin Drainages

There are three drainages in the Burt Basin with recorded populations of *L. unicolor*: Day, Napperby and Dashwood creeks. These are occasionally linked by surface waters flooding into Lake Lewis although only Napperby Creek has a defined channel feeding directly into the lake. Two other drainages also reached the lake following heavy rain in February 2000, based on interpretation of a satellite image from 1 March 2000: The Derwent and Gidyea Creek. The longest lasting waterhole is probably in Day Creek (North Twenty Mile Waterhole; M. Lines pers. comm.) and although not large may be permanent. However, there is a possibility that the current population of *L. unicolor* in the Burt Basin is also a result of translocation or recent migration. The two most likely pathways for migration from more robust populations in the Lake Eyre drainage division are from Davenport Creek in the Finke System and from the Todd River system via Sixteen Mile Creek.

There are several plausible cross over points where upper channels in the catchment of Davenport Creek (Finke system) are mapped as being within 500 m of tributaries of The Derwent (Burt Basin) on apparently level terrain, as determined from inspection of raster images of compilation material of 1:100,000 topographic mapping. These are in the general vicinity of Qualpa Dam and to the north of Tylers Pass.

Sixteen Mile Creek is reported to have reached Lake Lewis in 1974 (C. Connellan pers. comm.) and could have provided a link with the upper Todd River catchment, where minor channels of the two systems are within less than 1 km of each other on level terrain.

Comparison of Species Diversity and Assemblages Between Drainage Systems

The higher number of species in the Georgina River system is likely to be partly due to its great length and inter-connection with other Lake Eyre Basin drainages. The relatively high number of species in the

Finke River is attributed to the relative abundance of permanent waterholes and the diversity of habitat within them. In comparison, none of the large lowland waterholes of the NT portion of the Georgina River system is permanent (Randal 1978) or has substantial fringing vegetation, although several may be semi-permanent and one or two 'upland' waterholes at the base of the Toko Ranges are possibly permanent.

The Finke River system has the most distinctive assemblage of fish species, with nine species, three of which are endemic. Although the Georgina River system has more native species (10 or 11), all but one occur in other inland drainages. The exception is *Glossogobius aurea* (Gobiidae), which is, however, widespread in drainages of the north coast. Two of the endemic Finke system species are the only arid NT members of their genus:

- *Craterocephalus centralis* (Finke Hardyhead) – Atherinidae;
- *Chlamydogobius japalpa* (Finke Goby) – Gobiidae.

Furthermore, *Craterocephalus centralis* is the only member of the Atherinidae family in the arid NT.

Whistleduck Creek has the most naturally occurring species of the Davenport Rivers with two species that are not known from any of the other rivers of the Davenport or Murchison ranges: *Ambassis* sp. (Glassfish) and *N. erebi* (Bony Bream). All of the indigenous Whistleduck Creek species (or extremely close relatives), occur in the Finke River indicating that the fish assemblages of these two rivers are more similar to each other than to the Georgina River system, which has no known species of *Mogurnda* and has five additional species and one additional family to both the Finke River and Whistleduck Creek. Fish populations of both the Finke and Whistleduck systems depend on waterholes in or close to ranges, with generally clear water and which depend to varying extents on groundwater discharge for their persistence. In the Georgina system, such environments are quite rare and that system is characterised by its vast length, its connection to the Diamantina River and Lake Eyre, and large in-channel waterholes which are generally highly turbid (muddy). The fish habitat in the Davenport and Murchison ranges portion of the Barkly Basin is substantially different from the rest of the Barkly Basin, which is characterised by large long lasting riverine waterholes, similar to those of the Georgina River system, plus various temporary swamps. This difference in habitat may be causal to the presence of *Mogurnda* sp. in the ranges but not on the black soil plains.

There are several habitat differences between the Finke River system and Whistleduck Creek, which may explain the absence of *Chlamydogobius* and *Craterocephalus* in the latter. The most visually obvious difference is the lack of dense fringing emergent aquatic vegetation in the Davenport Ranges, whereas many of the permanent waterholes of the upper Finke River have areas of dense fringing vegetation, predominantly composed of reeds (*Phragmites australis*) and Bullrushes (*Typha domingensis*). *Typha domingensis* occurs at similar latitudes to the Davenport Ranges but is not recorded from the ranges themselves. The frequency of high energy river flows may prevent its establishment in the long-term waterholes of the ranges. Another difference is temperature and particularly the sub-zero winter nights that are common in the MacDonnell Ranges, but much less so in the Davenport Ranges. The different species assemblages may also be strongly influenced by chance extinctions of some species and very limited opportunities for them to recolonise.

10.12 Overview of Introductions and Translocations (Australian Natives and Exotics)

No exotic-introduced fishes were caught in the survey associated with the inventory. Records from other sources are discussed here.

Only one reproducing population is known of fish that are exotic to Australia; *Gambusia holbrooki* (Mosquito Fish) present in the Illparpa Swamp and possibly in the adjacent Alice Springs Sewage Ponds. St Marys Creek, into which this swamp overflows, is not known to join the nearby Todd River but is expected to do so in exceptional floods. The following information is from Robert Henderson (pers. comm.). *G. holbrooki* were first caught in the swamp in 2000 by school students participating in the Water Watch program. The swamp was drained and pumped completely dry in 2000 but refilled from heavy rains in 2001 and was found to be repopulated with *G. holbrooki*. Three other populations of *G.*

holbrooki in Alice Springs, in the John Flynn Uniting Church Pond and two private residences, were eradicated in 2000 and a media campaign and active investigation did not discover any other populations (R.Henderson pers. comm.).

Several specimens of an aquarium fish - *Xiphophorus maculatus* (Platy) - were collected by R.Henderson from a storm water drain in a residential area of Alice Springs in 2001. There is no evidence of a sustaining wild population, and the specimens found are assumed to have resulted from an aquarium release (R.Henderson pers. comm.).

There are various records of *Gambusia* and closely related species in or near to the Todd River system. Davis (1995) states that Mosquito Fish (*Gambusia affinis*) have been recorded at John Hayes Rockhole in the Todd River system, and this is assumed here to be the same infestation referred to by Unmack (2001a) as *Phaloceros caudimaculatus* (Speckled Mosquitofish, One-spot Livebearer). Unmack (2001a) lists dates, localities and museum specimen numbers for: a 1973 collection from Trepkina Gorge; a 1977 collection from John Hayes Rockhole; and a 1982 record by Thompson, from the Flynn Church pond, in Alice Springs. All these places are in or connected by flooding to the Todd River. Unmack (2001a) further records that the John Hayes population was subsequently poisoned, based on verbal information from Helen Larson of the Northern Territory Museum. Glover and Sim (1978a) and Merrick and Schmida (1984) record that *Gambusia affinis* was dispersed throughout Australia before and during World War 2. Allen *et al* (2002) describe another species, *Gambusia dominicensis*, that is poorly known and of similar appearance to *G. holbrooki*, and was apparently introduced in the vicinity of Alice Springs in the 1940s and 50s but may no longer persist. Larson and Martin (1990) state that both *G. affinis* and *G. dominicensis* were introduced to the NT in wartime. Storrs and Finlayson (1997, p.27) refer to the presence of *Gambusia holbrooki* at '2 or 3 sites in central Australia that were associated with WWII railway/military establishments'. Unmack (2001a) notes that records of *Gambusia dominicensis* from the Alice Springs area, as reported by Glover and Sim (1978) and Glover (1982), may be referable to *Phaloceros caudimaculatus*.

Wager and Unmack (2000) report that *Gambusia holbrooki* (Mosquitofish) are spreading in the Diamantina River and so they may well eventually spread to the Georgina River, including NT portions.

All species of *Gambusia* are declared noxious fish under Schedule 1 of the Northern Territory Fisheries Act and Fisheries Regulations.

Davis (1995) and Unmack (2001a) report a 1986 record of *Xiphophorus helleri* (Swordtail) from a dam near the Pine Gap defence facility, and Unmack (2001a) cites a 1982 collection by Thompson from Heavitree Gap in the Todd River.

Unmack (2001a) reports a record of an unidentified specimen of Cyprinodontidae (Killifish), collected from Pine Gap dam from 1975. In the past, the dam near Pine Gap may have been used frequently as a release site for unwanted aquarium fish and a place for catching new ones (information from Brendan Heenan, related by R. Henderson). Inspection in 2001 by R. Henderson indicated an absence of any fish. However, species of Cyprinodontidae must be considered a significant feral threat due to the ability of their fertilised eggs to withstand partial dehydration. Mills (1981) states that 'the so-called annual fishes whose watery habitat completely dries up each year, lay their fertilised eggs in the mud of the stream bed, where they survive the rest of the dry season in a dormant state' and further that 'the ability to withstand semi-dehydration has allowed aquarists to exchange fertilised eggs through the post, often on a worldwide basis'.

Information was obtained from a landholder that *Perca fluviatilis* (Redfin), native to Europe, were introduced to the Finke River in the 1950's, in the Henbury – Palmer Valley area (M. Lines pers. comm.), but there is no evidence that they have persisted there.

Macquaria ambigua subsp. ambigua (Golden Perch, Yellowbelly) is native to the Murray-Darling river system. Golden Perch also occur in the drainages that flow into Lake Eyre, including the Georgina River, but may be a distinct species (Wager & Unmack 2000; Allen *et al.* 2002). These are referred to here as *Macquaria sp. (Lake Eyre)*. At least one species of *Macquaria* has been introduced to Whistleduck Creek and is regarded by Wager and Unmack (2000) as *Macquaria ambigua subsp. ambigua*. According to a landholder, there have been at least two introductions of *Macquaria* species (Golden Perch) to Whistleduck Creek, at least one of which may have been from Cooper Creek stock and thus may have been *Macquaria sp. (Lake Eyre)* rather than *Macquaria ambigua*. Apparently they are still present.

Macquaria species have been stocked into waterholes of the Barkly Tableland. It is not known which taxonomic entity have been stocked, and it is possible that the Murray-Darling entity has been introduced, which may interbreed with the Lake Eyre entity. A species of *Macquaria* has been introduced to the Elkedra River. There is anecdotal evidence that the Elkedra population is persisting. Unmack (1995) records that a species of *Macquaria* was confirmed as occurring in Jervois Mine Dam, from photographs of fish caught there. As this dam dries out periodically the species will not persist unless re-introduced. Unmack (2001a) also records that *Macquaria ambigua* was stocked into dams on Mt Riddock Station in the Plenty River catchment. There is a recent anecdotal report of *Macquaria sp.* stocked in dam on Undoolya Station (G. Fyfe pers. comm.). Mr Sean Leigh of Murray Downs Station, interviewed in this survey, referred to fish he had caught in Hatches Creek on the Frew River as Cod. These may have been *Maccullochella peelii* (Murray Cod), which Unmack (2001a) states has been introduced somewhere in the arid NT, or a species of *Macquaria* which is broadly similar. There is anecdotal evidence that waterholes in the Elkedra River have been stocked with *Maccullochella peelii* (Murray Cod) and are persisting. It is not known whether species introduced to the rivers of the Davenport Ranges have formed self sustaining populations.

Wager and Unmack (2000) report the introduction of another species of Australian native that is not indigenous to the NT: *Bidyanus bidyanus* (Silver Perch) in Whistleduck Creek.

A cattle station owner interviewed during our survey reported the introduction of Golden Perch, Silver Perch and Spangled Grunters to Mount Esther Dam on Anningie Station in the 1980's and that the dam has not been dry since (M.Lines pers. comm.). The persistence of those introductions is not known. Golden Perch is assumed to have been *Macquaria sp.* and Silver Perch to have been *Bidyanus bidyanus*.

Fleming *et al.* (1983, p.31) report 'Yellow fin' in the Frew River 'based on local informants'. This may indicate some other introduced species or may have been a reference to 'Yellowbelly' (*Macquaria sp.*).

There have been various translocations of *Leiopotherapon unicolor* (Spangled Grunter) to dams from naturally occurring populations in the arid NT, with occasional and ongoing populations establishing in various natural waterways which previously did not have fish in them. According to Max Lines (pers. comm.), translocations have been made to the Hanson River and Lander Rivers from Napperby Creek, and to the Aileron Homestead Dam from Mueller Creek (Sandover River system).

10.13 Conservation Status of Natives and Threats

Various organisations independently assess the conservation significance of Australian species of fish. One of the arid NT species is officially listed as threatened under Northern Territory legislation: *Chlamydogobius japaipa*.

Australian Society for Fish Biology Threatened Fishes Committee

Two species are listed by the Australian Society for Fish Biology (ASFB) in the 2001 report of its Threatened Fishes Committee (internet site for ASFB):

- *Chlamydogobius japaipa* V (Vulnerable according to IUCN criteria);
- *Craterocephalus centralis* LR-N (Lower Risk – Near Threatened according to IUCN criteria).

The Australian Society for Fish Biology has a leading role in assessing the conservation status of fish species with information on this published on their web site (Internet site of ASFB). In the 1999 report of the ASFB Threatened Fishes Committee (internet site for ASFB), both the above species are also listed as 'Restricted'; a risk category then in use by the ASFB:

'RESTRICTED Taxa which are not presently in danger but which occur in restricted areas, or which have suffered a long-term reduction in distribution and/or abundance and are now uncommon.' (p.11).

This category intuitively applies well to both *C. japaipa* and *C. centralis*, as there is no established threatening process or evidence of declining population. Consistent with this assessment, Allen *et al.* (2002) state that both species are apparently common or abundant throughout their limited range. However, the IUCN criteria do not depend on the identification of threats, and it is not surprising that the

two species also qualify as V and LR-N based on either the restricted area of the population or the relatively low population numbers.

The Action Plan for Australian Freshwater Fishes

The Action Plan for Australian Freshwater Fishes was prepared for the Commonwealth Government by Wager and Jackson (1993). They listed *Craterocephalus centralis* as Rare, a category then in use by the Australian National Parks and Wildlife Service Endangered Species Program. As *Chlamydogobius japaipa* was not described as a species in 1993, it was not listed in the action plan. The Action Plan has not been updated since 1993, but it includes a recommendation that the ASFB 'Threatened Fishes List form the basis for all other conservation status listings for fish'.

Northern Territory Legislation

The following fishes are listed under the Territory Parks and Wildlife Act, using IUCN version 3.1 assessment criteria and significance codes (IUCN 2001):

Chlamydogobius japaipa IUCN category = Vulnerable (Criteria B1ab(iii)+2ab(iii))

Craterocephalus centralis IUCN category = Near Threatened

Mogurnda larapintae IUCN category = Near Threatened

Mogurnda sp. (Davenport Ranges) IUCN category = Data Deficient

The main IUCN criteria (IUCN 2000) used to classify *Chlamydogobius japaipa* as vulnerable are B1ab(iii) and B2ab(iii).

Criterion B1a is extent of occurrence less than 20,000km² and severely fragmented (≤ 10 locations). The permanent pools that provide drought refuge are an appropriate basis for determining 'area of occupancy' and number of locations. There are more than 10 separate permanent waterbodies in the Finke, however *C. japaipa* has not been recorded at all of them. If the number of known drought refuges for *C. japaipa* is subsequently found to be more than 10, then that species will not qualify as vulnerable under B1a or B2a.

Criterion B1b(iii) is more subjective being a 'continuing decline, observed, inferred or projected, in area, extent and quality of habitat'.

Criterion B2b(iii) is area of occupancy estimated to be less than 2000km² and estimates indicating that it is severely fragmented (a) and that there is a continuing decline, observed, inferred or projected in area, extent and/or quality of habitat. In the case of *C. japaipa* the decline is inferred or projected, since quantitative data are lacking.

Criteria B1c(i,ii,iiiiv) and B2c(i,ii,iiiiv) may also qualify this species as Vulnerable based on the extreme fluctuations of the extent (and presumably also in the size of the population) within the river.

Criterion D2 may also qualify this species as Vulnerable: area of occupancy $< 20\text{km}^2$.

Although *Craterocephalus centralis* has been recorded in more parts of the catchment than *C. japaipa*, it is unlikely to occur in a greater number of drought refuges and so may also qualify as Vulnerable.

Mogurnda sp. (Davenport Ranges) was classified as Data Deficient due to the uncertainty about its taxonomic status. If it is described as a new species or subspecies then it will qualify as either Vulnerable or Near Threatened depending on the number of drought refuge pools.

Mogurnda larapintae has been recorded from the Palmer River section of the Finke system, including from at least one confirmed drought refuge. This, and limited evidence that it is relatively abundant are the main basis for considering it to be more secure than *C. japaipa*. It is also possible that *Mogurnda sp. (Davenport Ranges)* will prove to be a disjunct population of *M. larapintae*.

Further survey work is required to assess the status of these species with more certainty.

Threats

The Finke River fishes are moderately well protected, with a high proportion of the permanent pools being in the West MacDonnell and Finke Gorge national parks, although two that may be the most permanent are not in reserves; being Running Waters and Illara Waterhole (P. Latz pers. comm.). In the Davenport Ranges, many permanent and long-term waterholes are in the Proposed Davenport Ranges National Park, including most of the headwaters of the Frew River and Whistleduck Creek, with their potentially distinct species.

Various processes that threaten populations and species of fish are listed in *The Action Plan for Australian Freshwater Fishes* (Wager & Jackson 1993), but luckily, most do not presently pose an imminent threat in the arid NT. The introduction of diseases via fish introductions is a potential threat as is chemical pollution and competition from introduced species. The relatively small number of permanent pools that provide drought refuge is a key component of the vulnerability of arid NT fishes. In the past, intense grazing pressure reduced the abundance of fringing aquatic vegetation in some of the permanent waterholes of the Finke River system, but changed management practices including feral horse control have resulted in recovery (P. Latz & D. Matthews pers. comm.). Accelerated erosion and siltation are among the processes which may be adversely affecting arid NT fishes, but there is limited information of current and pre-historic siltation levels. Current land uses and fire regimes may have resulted in increased erosion rates in fairly recent times (P. Latz pers. comm.).

A study of the effects of high energy river floods on fish populations in the USA (Minckley & Mefee 1987, p.100) found that *Gambusia affinis* populations are 'decimated by flooding'. The drought refuges in the Finke River are all prone to high energy floods, which may provide a natural control on *Gambusia* if it ever becomes established in the Finke system. However, the long periods of several years that can occur between floods might allow *Gambusia* to adversely effect indigenous species.

10.14 Appraisal of Survey Methods

The sampling was essentially opportunistic and rarely were all the methods used at a particular water body. Accordingly, the data obtained only confirms the presence of species whilst providing little evidence of the absence of species. The difficulty of obtaining a complete list of species present in a water body depends on the methods used, the abundance and habits of the species as well as the nature of the waterbodies and the time that was available for sampling.

To ascertain the full list of species present at a site with any confidence would require more intensive and systematic sampling, over a longer period than was possible on this survey, and would have been well beyond the scope of this study. Additional methods that could be employed in a more thorough fish survey include: electro-fishing, gill-netting and poisoning. The methods used in our survey were effective given the time constraints and yielded valuable new distribution records plus samples for genetic analysis.

Seine netting was effective where fishes were abundant and particularly where the water was turbid. Seining was also effective in clear water, where the water body was small or had confined sections in which fish could be trapped against or washed onto a bank. A selection of seine nets with different lengths and mesh sizes would have improved sampling. The use of seine nets was limited to water shallower than about 1.3 metres. Other aspects of some waterbodies also made them difficult to use and as a result less effective: large stones or vegetation that snagged the net; soft sediments that were difficult to walk on; and floating aquatic vegetation that clogged the net.

Cast netting was effective for larger fish in waterbodies that could not be seined easily and in very clear water, where most species easily eluded our 2 metre seine net. It is also useful for species that are more active at night such as *Neosilurus hyrtlii*. Most, but not all, catches of *Neosilurus hyrtlii* were made at night with a cast net. These fish are very wary during the day. In the pools where they were caught by day (upper Frew River) individuals hid effectively as soon as the pool was disturbed. In our survey, using a cast net at night, we added *Neosilurus hyrtlii* to the known species for Kurundi Creek. Use of a seine net by day, in the shallow end waters of the same waterhole, did not catch this species. Kurundi Creek was surveyed by Bishop and Moses (1983) using an array of techniques: seine nets (2 & 26 mm), multi-panel gill net (26 – 150 mm) and poison. The only species caught was *Leiopotherapon unicolor*, which

they concluded was probably the only species present. It is possible that *Neosilurus hyrtlui* was absent from Kurundi Creek when surveyed by Bishop and Moses (1983).

In our survey, some records of *Mogurnda* species were obtained by seine netting and one was caught in a cage trap, but most were from hand netting of individuals that had been observed at night or uncovered by rock turning.

We failed to catch any of the non-indigenous angling species introduced to three drainages which we fished: *Macquaria sp.*, *Bidyanus bidyanus*, and *Maccullochella peelii*. Similarly, we didn't catch any *Macquaria sp.* (*Lake Eyre*) in the Georgina River. It is possible that the behaviour of both *Macquaria* and *Maccullochella* helped them elude our cast net and short seine nets. *Macquaria sp.* (*Lake Eyre*) have been caught in the Georgina River with a much longer, multi-panel, seine net (H. Nix pers. comm.).

Use of a standard portable fridge/freezer running from a 12 volt vehicle battery proved sufficient for preserving specimens for subsequent genetic analysis (M. Adams pers. comm.) and avoided the need for a liquid nitrogen canister. Due to the short stays at sites and large distances traveled between many sites, no problems were experienced with low charge in vehicle batteries (2 batteries in each vehicle, which was a Toyota Landcruiser trayback utility). Keeping sufficient charge in the vehicle battery may be an issue in other styles of survey.

Our survey did not include recording of water temperature, limiting the potential contribution of our data to research into environmental tolerances of fishes. However, the knowledge of the distribution of species of fishes has been advanced by our opportunistic survey. This is indicative of the general lack of sampling in the arid NT.

10.15 Identification Guides and Sources of Other Information

Various published books and internet sites provide good general descriptions of the arid NT fish species and these are listed below. When used with our annotated species list they will allow most specimens to be identified. None of them include formal keys to species.

The most recent is the *Field Guide to the Freshwater Fishes of Australia* (Allen *et al.* 2002), which includes formal identification details but does not give thorough distribution information relevant to the arid NT for all the species that occur here. The *Fishes of the Lake Eyre catchment of central Australia* by Wager and Unmack (2000) includes all the species for the arid NT, with excellent distribution information and descriptions but does not include formal identification details.

Various other guides to Australian fishes have been published, with colour photographs and assorted information that complement Allen *et al.* (2002) and Wager and Unmack (2000). Of particular relevance is *Freshwater Fishes of the Northern Territory* by Larson and Martin (1990). Other guides consulted in preparing this report are *Australian Freshwater Fishes – Biology and Management* by Merrick and Schmida (1984); *Freshwater Fishes of South-eastern Australia* (McDowall 1996); *Freshwater Fishes of Australia* (Allen 1989); and *Australian Freshwater Fishes* by Lake (1978).

Peter Unmack maintains an internet site with a great deal of information on fishes of the Australian arid zone, including a detailed bibliography: the 'Australian Desert Fishes Pages' (internet site: ADFP).

Several other organisations maintain web sites with useful information about Australian inland fish. Native Fish Australia is a volunteer organisation with a web site dedicated to Australian native fish (Internet site of NFA) which includes information on various species. The Australian Society for Fish Biology also has an informative web site (Internet site of ASFB). The Australian Museum maintains a valuable set of information about fish on its internet site, but it does not currently include all arid NT species (Internet site of Australian Museum Fish Site; & Internet site of AMOL-fishes). Another useful site is FISHBASE (internet site of FISHBASE). FISHBASE is a relational database – available over the internet – with information about almost all fish species around the world. It was developed by the International Centre for Living Aquatic Resources Management (ICLARM) in collaboration with many partners including the United Nations Food and Agriculture Organisation (FAO).



11. Invertebrates in Arid NT Wetlands

Scope

Aquatic invertebrates are important elements of the wetland biota, however, there has been little systematic survey in the arid NT. The exceptions are long-term waterholes in the West MacDonnell Ranges and in the George Gill Range.

This chapter provides a brief introduction to some aspects of the invertebrate fauna of arid NT wetlands, and to existing studies and reviews from elsewhere in the Australian arid zone.

The invertebrate flora of temporary wetlands changes significantly through an inundation event (R.Henderson pers. comm.) and considerable sampling effort is required to characterise their invertebrate communities. Invertebrate work is particularly time consuming, with a pilot study in Victoria recording processing time of up to 50 hours for 2 minutes of field sampling (Butcher 1999). Accordingly, no detailed study of invertebrates was undertaken in this inventory, however opportunistic observations and samples may have added a little to a relatively sparse knowledge base.

11.1 Summaries of Pre-existing Surveys and Reviews

General Reviews of Inland Aquatic Invertebrates

There are various publications reviewing the range of aquatic fauna in inland Australia, including identifications guides. These include: *Life in Inland Waters* (Williams 1983); *Australian Freshwater Life* (Williams 1980); the *Colour Guide to Invertebrates of Australian Inland Waters* (Hawking & Smith 1997); Williams and Campbell (1987); Williams and Allen (1987); Williams (1985, 1998a, 1998b, 1998c, 1999); and Yen and Butcher (1997).

Williams (1998a, 1998b & 1998c) summarises knowledge of the invertebrate fauna of Australian inland wetlands including the origins of the fauna (Williams 1998c).

Salt Lakes

Williams (1998b) summarises the fauna of Australian salt lakes, however, most of the information appears to be from South Australia and Western Australia.

Williams (1998) suggests that the aquatic fauna of arid zone salt lakes is distinctive but that it may not vary much between different lakes:

‘The aquatic fauna occurring in them is much less regionally restricted. Many of its taxa have wide distributions. It is also taxonomically different from the fauna of south-western and south-eastern salt lakes.’ Williams (1998b, p.163)

The distinctive fauna of salt lakes in Australia may have evolved in the more predictably wet salt lakes of south-eastern and south-western Australia, whilst those in central Australia went through periods of such aridity as to preclude this (Williams 1998b).

Much of the data on central Australian salt lakes is from Lake Eyre, which probably had and has a more predictably filling regime than many others due to inflow from the tropics via the Georgina and Diamantina Rivers. Williams (1998b, p.165) suggests that:

‘The fauna of central lakes, therefore has evolved elsewhere and occurs there only because it has (i) good dispersal mechanisms which enable it to take rapid advantage of the presence of suitable habitats, as well as (ii) mechanisms to survive long periods between major inundations ...’

There is some evidence that there is a distinctive and predominantly terrestrial fauna also associated with playa lakes, particularly beetles which use the lakes when dry (P.Hudson pers. comm.; Williams 1999). This dry phase fauna may be more regionally restricted than the aquatic fauna (Williams 1998b).

Williams (1985) reviews physical and chemical characteristics of temporary inland (standing) lentic waters and the adaptations of the biota that live there. This includes strategies for surviving desiccation, avoidance by highly mobile taxa (birds and some insects), dormancy or drought resistance as adults, eggs, cysts, seeds and spores and vegetative parts in some plants.

Rivers and Springs in the MacDonnell Range Bioregions

The 1894 Horn Expedition sampled invertebrates in the spring-fed pools at the base of the George Gill Range, and in waterholes in the Finke River. The results of the Horn expedition are compared with more recent data by Davis (1996).

Williams and Siebert (1963) published the first report on the chemical composition of permanent and semi-permanent waterholes in central Australia, including an indication of those thought to be recharged from ground-water. They included a preliminary list of invertebrates from 5 of the West MacDonnell Ranges waterholes.

The only systematic surveys of aquatic fauna have been in the long-term pools of the George Gill Range and in the West MacDonnell Ranges. The survey in the George Gill Range is reported in Davis *et al.* (1991 and 1993) and the West MacDonnell's work in Davis (1995) and comparisons of the two areas are presented in Davis (1997). Although they are the best available, most of the sites were only sampled once. The work so far shows that both the George Gill pools and those in the West MacDonnell's have a diverse fauna, which are distinct from each other, and have relictual components (Davis 1997).

A great deal of further work is required to record the changes in species abundance and activity at different times of the year and through variations in water level and chemistry at temporary waterholes in the upper Finke River System. Semi-permanent spring-fed pools in the Palm Valley area are likely to have different aquatic fauna assemblages due to their generally shallow nature and relatively high salinity compared to most of those others sampled by Davis *et al.* (1991) and Davis (1995). However, they were not included in the reported numerical analysis by Davis (1997).

An important result of the surveys in the George Gill Range and West MacDonnell's was the identification of a group of sites termed 'relict streams'. These are small streams and pools created by permanent flowing springs with low salinity which had populations of the Water Penny (*Sclerocyphon fuscus*).

The Water Penny (*Sclerocyphon fuscus*) is an aquatic larvae of a terrestrial beetle that requires fresh water. It is believed to be a relict of moister climate which depends on permanent fresh water. In central arid Australia it is only known from a few locations in the West MacDonnell Ranges (7 sites) and the George Gill Ranges (Warrkra-Kings canyon area: 2 sites) (Davis 1995). The West MacDonnell sites are, from west to east: Talipata Springs; Talipata Gorge; Bowmans Gap area ('Possum Springs'); (Mount) Giles Springs; Giles Yard Springs; upper Serpentine Gorge; and upper Hugh Gorge. The George Gill sites are upper Stokes Creek and Penny Springs. Its main population range is in Victoria and southern South Australia (Davis *et al.* 1993). The Mount Giles Spring record referred to by Davis (1995) was apparently from 1986 and may be dubious given the confusion between that spring and Giles Yard Springs. At some sites there are moderately high flows of spring water compared to the other sites where flow may be just a trickle, such as the George Gill sites (D.Schunke pers. comm.).

Other Surface Wetland Types

There has been virtually no systematic sampling of the aquatic invertebrate fauna of other wetland types. Bayly (2001) undertook repeated sampling of invertebrates in a small gnamma hole on a granitic outcrop near Papunya and compares the invertebrate fauna to gnamma holes in south-western Australia. Fauna at the Papunya site included a species that was previously thought not to occur in Australia and new species

of ostracods and nematodes. The nematodes are described in Nicholas and Hodda (2000, cited in Bayly 2001). These results are indicative of the extremely poor knowledge of the invertebrate fauna.

Sampling by school and community groups involved in the Waterwatch Program has indicated large changes in faunal assemblages through time, in temporary waterbodies (R.Henderson pers. comm.). Environmental education in various Aboriginal community schools has also involved sampling aquatic invertebrates (T.Nano pers. comm.).

Underground Aquatic Fauna

A unique group of aquatic invertebrate fauna live only in underground habitats and are called 'stygo fauna' (Humphreys 2001). Whether or not such fauna should be included under the wetlands banner may be vigorously debated, however, subterranean karst wetlands are clearly included under the Ramsar Convention.

To date the only work on stygo fauna in the arid NT is sampling done by Humphreys in 2001 and 2002 (R.Read pers. comm.). Two bores in Proterozoic limestone near Alice Springs yielded no stygo fauna. However sampling in calcrete aquifers in the Ngalia Basin found many species, including eight new species of diving beetle.

A special edition of the *Records of the Western Australian Museum* is devoted to Australian subterranean fauna: *Subterranean Biology in Australia 2000* (Humphreys & Harvey 2001). It includes results of far more extensive sampling of calcrete aquifers in paleovalleys in West Australian areas of the Australian arid zone (Humphreys 2001) which are summarised here as follows. Paleovalleys or paleodrainage systems in the Western Shield are hydrologically isolated from each other and each one sampled contains a unique and diverse stygo fauna. Further more, within the paleodrainage systems hypersaline sections, often associated with surface salt lakes, appear to serve as barriers that isolate stygo fauna in separate sections of the same system.

It is expected that there is also a substantial aquatic invertebrate fauna in saturated soil and sand below and adjacent to rivers and swamps (the hyporheic zone), based on work interstate (reviewed by Boulton 2001). It seems possible that endemic species may exist in the hyporheic zone in areas of permanent surface or subsurface ground water discharge, particularly in the Finke River.

11.2 Inventory Survey

Overview

Aquatic invertebrates were sampled opportunistically in the survey component of the arid NT wetlands inventory. The main methods were dip netting and seining with a 2 m wide seine net. Samples were stored in 70% ethanol and sorted to order and family. Our sampling was rapid, did not target different sub-habitats and was based on a single visit to each site. Therefore, it was insufficient to document faunal assemblages for wetland types. Some of the invertebrate work was a collaboration with Bernadette Bostock of Deakin University and some specimens of *Branchinella sp.* were retained at Deakin University for further research. All other specimens will be either lodged with the Northern Territory Museum, or retained as reference material at the Arid Zone Research Institute.

The data from the survey are listed in Volume 2 of this report.

Most of the sampling undertaken was in relatively open and shallow waters, including riverine waterholes, claypans and other freshwater lakes. Such sites were generally seined providing a reasonably effective one off sample of the limnetic zone. At a few sites, dip netting was conducted around emergent vegetation and on the margins of deeper water, including some rock holes. Drop nets, mesh cages and funnel traps were also used at a few sites.

The abundance of invertebrates was not quantitatively measured, but was observed to vary greatly between sites. At one claypan in the Barkly Tableland, by far the highest abundance was observed with many thousand individuals caught in each sweep of the seine net. Abundance was generally highest in the Barkly Tableland, which was presumed to be due to generally higher temperatures than at more

southerly sites. Most of the sampling was in cooler months (April-September), but Lake Mackay was sampled in October.

Distribution of Crustaceans

Various crustaceans are recorded from the arid NT including brine shrimps (*Parartemia spp.*), shield shrimps (*Triops australiensis*), fairy shrimps (e.g. *Branchinella spp.*), freshwater prawns (*Macrobrachium spp.*), Ostracods (Ostracoda), crabs (*Holthuisiana transversa*) and yabbies (*Cherax spp.*). Apparently collections of a fairy shrimp (*Branchinella sp.*) from the south-east of the study area have attracted interest from aquaculture researchers (B.Bostock pers. comm.).

In addition to opportunistic sampling, observations were made regarding larger invertebrates and their impacts. This mostly applied to burrows/holes in earth banks that were assumed to be from crustaceans, either the Yabby (*Cherax destructor*) or the Inland Crab (*Holthuisiana transversa*), or both. A third (introduced) large crustacean is known: Redclaw (*Cherax quadricarinatus*). It was only recorded once, at Wycliffe Creek, where it has apparently formed a self sustaining population since introduction over 10 years ago (D.Debney pers. comm.). There is also anecdotal evidence that introduced Redclaw are persisting in Kurundi Creek (P.Saint pers. comm.).

Due to relative ease of observation and abundance of records, the distributions of crabs and yabbies are discussed here in some detail.

Observations of Burrows/Holes

Two forms of burrow were observed. The most common were simple holes in earth banks of drainage lines, including waterholes. Less often, conical mounds had been constructed to elevate the burrow entrance. Both types were assumed to be either from Yabbys or Crabs, however, excavation showed them to be very deep and none were excavated to their full extent and no animals were observed in the holes. At one site with conical burrows, Crabs were caught in the adjacent waterholes (Wall Hole on Coglín Creek). It is likely that most of the holes seen were from crabs.

Boulton and Brock (1999) discuss a group of invertebrate fauna which utilise crayfish and crab burrows, called 'phoeteros'. Jones and Morgan (2002, p. 204) note that *H. transversa* burrows 'may extend 1m into the ground and during the dry season they are plugged with earth by the crab. Within its damp burrow the crab can survive until the following wet season'. It is possible to 'attract' crabs out of their burrows by pouring water into the holes (Lynn Day pers.comm.).

Distribution of *Cherax destructor*

Populations of Yabbies (*Cherax destructor*) that were encountered by the Horn Expedition are considered to be indigenous, although it is possible they were previously translocated by workers on the Overland Telegraph Line or by early non-aboriginal travelers. The Horn Expedition recorded *C. destructor* at Running Waters and Hermansburg in the upper Finke River.

Yabbies were recorded at five locations in our survey. Those at Two Mile Waterhole on the upper Finke River and at Nora Waterhole in the Georgina River system (Toko Ranges tributary), are considered indigenous. Three other records are presumed to be introductions. One, at Allungara Waterhole, is presumed to be from a stock dam as the drainage system is isolated in the Burt Plain and has no long-term natural waterbodies. One, in the upper catchment of Lilla Creek in the lower Finke River system was confirmed as resulting from introduction to a stock dam. The third was at Conlans Lagoon, a claypan/swamp near Alice Springs. This swamp is adjacent to Roe Creek, which in high flows may link Conlans Lagoon to swamps and pans in the Illparpa Valley, where yabbies have also been introduced.

Populations at Bagot Creek and Stokes Creek in the George Gill Range are considered to be re-introductions at some time since the Horn Expedition (Davis 1996).

The populations that are considered indigenous are all in systems with permanent waterbodies. The species was recorded at Nora Waterhole in the Toko Ranges by Fogarty *et al.* (1995) which is possibly permanent. The large near-seasonal waterholes in rivers of the Georgina System in the Mitchell Grass Downs bioregion may not have Yabbies, despite holding water for many months in most years. A station worker at Sudan reported catching only crabs in a cage trap at One Mile Waterhole on the Rankin River.

Distribution of *Holthusiana transversa*

In comparison to Yabbies, Crabs are much more widespread and were observed either directly, or by burrows, in a great many temporary watercourses as well as in temporary waterholes in watercourses. Crabs have been recorded in a variety of locations north of about 22° 44' latitude. To the south of this, the only records in the arid NT are from the Stony Plains Bioregion at Wall Hole (25° 57' 43"; this survey) and downstream at Charlotte Waters on the lower Coglein Creek (Horn Expedition). There is no record of *Holthusiana* in the MacDonnell Ranges Bioregion, either in the more elevated MacDonnell Ranges or in the other ranges with lower elevation and less relief (height above the plain), such as the George Gill Range.

Crabs are considered to be abundant in the Dulcie Ranges and Davenport Ranges. Of records to the north of the MacDonnell Ranges bioregion, the most southerly records were specimens from the Dulcie Ranges and observation of burrows at a large claypan and Bluebush swamp on Tarlton Downs Station (both at about 22° 44' S). Specimens or body parts were collected at various other locations including, Junction Waterhole on the Sandover River, creeks in the Reynolds and Yundurbulu Ranges, including some very temporary waterholes, waterholes in the eastern and northern drainages of the Davenport Range, both major and minor drainage lines in the Mitchell Grass Downs and Channel Country bioregions, and a claypan in the Mitchell Grass Downs.

Holes in banks were also observed in clay/loam banks of minor upland creeks in the Dulcie Ranges and Reynolds Range; and in a bank of a sandy river bed (Woodforde River) with no waterholes in the vicinity. Although these observations cannot be confirmed as being burrows of *Holthusiana*, if they are, then they may be indicative of a broad range of inundation regimes that the inland crab can tolerate. Alternatively, they may indicate surprisingly long range dispersal from areas with more frequent inundation regimes. The distribution and physiology of inland crabs (*Holthusiana transversa*) were reviewed by Greenaway (1984) and report that they survive dry periods in 'dry' burrows but may depend on some soil moisture to prevent unsustainable loss of body moisture.

Relative Distributions of Crabs and Yabbies

Specimen records of *Cherax destructor* and *Holthusiana transversa* from the Northern Territory Museum do not add to the distribution ranges described above, apart from a record of Yabby from the Todd River in Alice Springs, which is almost certainly an introduction.

The relative distributions of Crabs and Yabbies are somewhat enigmatic. Both are believed to be indigenous to the study area, but there have been many introductions and translocations of both Yabbies and Redclaw.

Three factors are proposed as possible contributors to the apparent absence of crabs between the latitudes of 22° 44' S and 25° 57' S. Firstly, frosts may be more frequent and severe in the MacDonnell Ranges than elsewhere in the arid NT. The substantial heights of some ranges may produce cold air drainage such that drainage depressions at their bases are particularly frost prone. Temperatures are generally warmer at more northerly latitudes and frosts are rare. The second factor is the extreme variation in rainfall in the area such that the majority of the riverine environment is dry most of the time and possibly to a greater extent than those further north in the study area. The third factor is the relative isolation of the greater MacDonnell Ranges from less arid parts of the continent.

There is no record of the co-existence of crabs and yabbies in the study area, but this cannot be ruled out. Both are recorded from the Georgina River system in the NT, and it is possible that their ranges overlap, even if their habitat preferences are sufficiently different that they do not directly compete. The most likely area of overlap is in the Toko Ranges. Further study of their possible interaction may assist with assessing the impacts of introductions and translocations of crustaceans, particularly Yabby and Redclaw,

and the potential risks to natural ecosystems of aquaculture enterprises. Crab shells were found at a waterhole on Wycliffe Creek where Redclaw were collected indicating co-existence.

Yabbies (*Cherax destructor*) were apparently translocated to the Henbury / Palmer Valley area of the Finke River in the 1950s (M.Lines pers. comm.). It is possible that they have interbred with what may have been a long isolated population of *Cherax destructor* that was already present in parts of the Finke as recorded by the 1894 Horn Scientific Expedition.

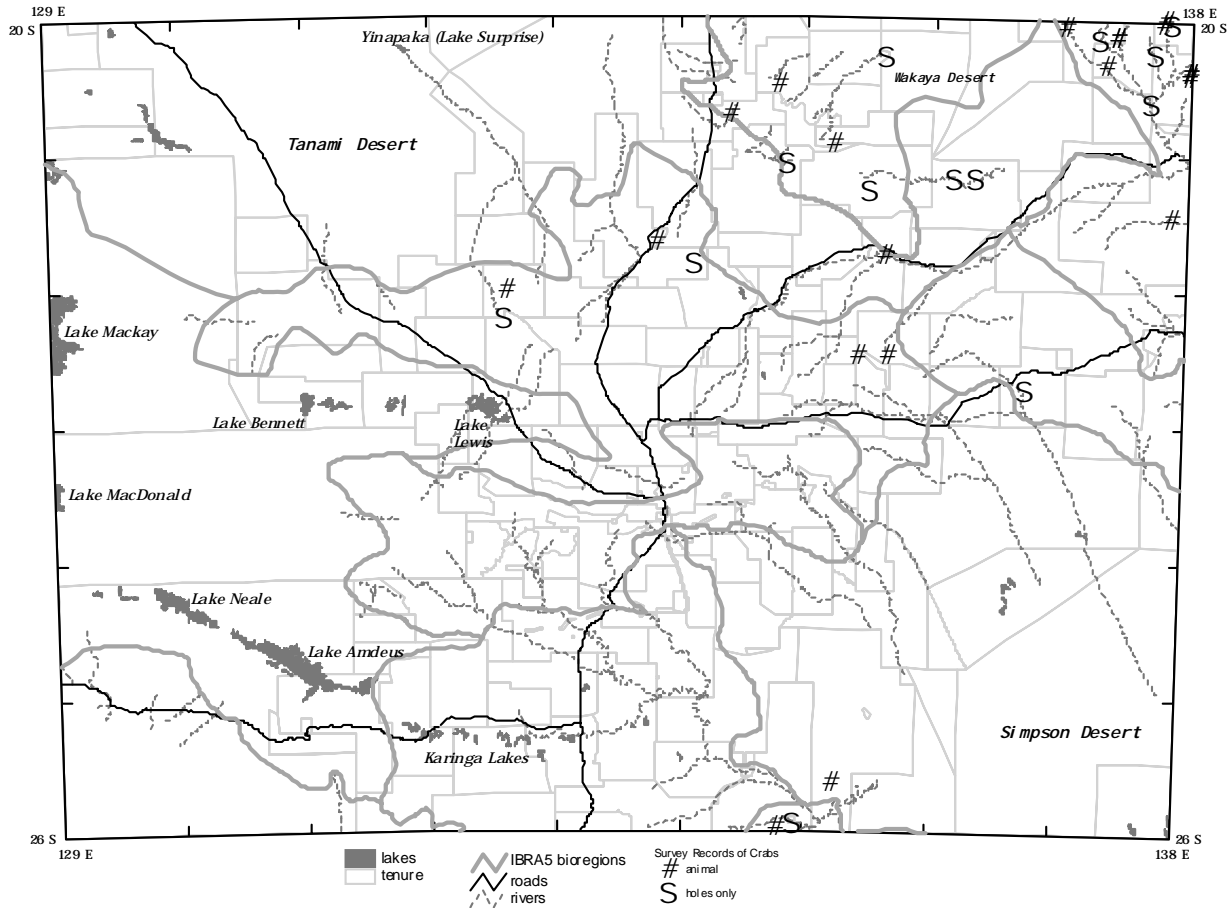


Figure 13. Survey records of inland crabs

Distribution of Mollusca (Snails and Mussels)

Gastropods were recorded at various sites including a long-term and possibly permanent spring-fed stream in the Dulcie Ranges, several floodout swamps, a non-permanent waterhole in the MacDonnell Ranges and a semi-saline lake. One station owner reported that aquatic snails were absent until about 20 years ago which may indicate dispersal by birds.

Freshwater mussels were abundant in the waterholes of the Georgina River system in both the Mitchell Grass Downs and Channel Country bioregions. Although not identified to genus, two distinct morphotypes were seen. The most abundant were large dark blue-grey shells, typically 10 cm by 5 cm of the family *Hyriidae*. These are probably *Vesunio wilsonii*, based on distribution maps in Williams and Campbell (1987) and on a NT Museum record of *V. wilsonii* from the Lake Nash area. The other morphotype were much smaller, pale to mid brown and probably of the family *Corbiculidae*. Anecdotal evidence suggests that large mussels occur in a single creek on Elkedra Station on the south of the Davenport Ranges. No other records of large mussels have been found indicating that in the arid NT they are virtually restricted to the Georgina River system.

Observations of Other Taxa

Leeches were observed at several sites with fish and have been reported from temporary rockholes in ranges. They seem to be able to colonise temporary waterbodies, possibly via hosts such as fish and frogs as well as by swimming.

Long thin worms, inconclusively identified as Horsehair Worms (Nematomorpha) were found in three disparate locations and habitats, all with shallow temporary water: temporary spring-fed pools in bedrock in the Dulcie Ranges, a minor rocky-alluvial creek in the Davenport Ranges and a small Lignum Swamp in the Finke Bioregion.

11.3 Aquatic Invertebrates and Waterbody Health

The knowledge of the invertebrate fauna of aquatic environments in the arid NT is insufficient for them to be used as indicators of 'environmental health' as is proposed for less temporary rivers elsewhere in Australia (e.g. Davis 1997b). Even the better-sampled long-term waterbodies in the MacDonnell Ranges bioregion have mostly been sampled a single time. Also the extreme variations in water level and in some cases in salinity mean that invertebrate assemblages for most wetlands are expected to be very changeable even without human related disturbances.



12. Amphibious and Terrestrial Vertebrates

12.1 Frogs

Apart from fish, frogs are the only ground dwelling vertebrate animals in the arid NT with a dependence on wetlands. Most frog species, but possibly not all, need surface water to lay eggs in, and as habitat for their tadpole stage. Any such water is a wetland under our broad definition, although some may be too small and ephemeral to be mapped or commonly perceived as wetlands. Tyler and Davies (1986) report that tadpoles of *Litoria rubella* can complete their tadpole stage in as little as 14 days. Some species are more closely associated with wetlands than others. For example, *Neobatrachus sutor* often breeds in claypans (Tyler & Davies 1986). Overviews of the adaptations to aridity in desert frogs can be found in Williams and Calaby (1985), in Tyler (1989), in Heatwole (1984) and in van Beurden (1984), and include burrowing and dormancy in desiccation resistant cocoons. Frogs were not included in the survey component of this inventory. The following list of frog species in the arid NT was created from pre-existing distribution records in the NT Fauna Atlas (a vertebrate fauna records database maintained by the Parks and Wildlife Service of the NT) from across the arid NT and not just from wetlands.

Table 32. Frog species known from the arid NT

Scientific Name	Common Name	No. of arid NT records in Fauna Atlas
<i>Cyclorana australis</i>	Giant Frog	19
<i>Cyclorana cryptotis</i>	Hidden-ear Frog	1
<i>Cyclorana cultripes</i>	Knife-footed Frog	112
<i>Cyclorana maculosa</i>	Daly Waters Frog	1
<i>Cyclorana maini</i>	Main's Frog	145
<i>Cyclorana platycephala</i>	Water-holding Frog	18
<i>Limnodynastes ornatus</i>	Ornate Burrowing Frog	2
<i>Limnodynastes spenceri</i>	Spencer's Frog	618
<i>Litoria caerulea</i>	Green Tree-frog	251
<i>Litoria coplandi</i>	Copland's Rock Frog	2
<i>Litoria gilleni</i>	Centralian Tree Frog	24
<i>Litoria rubella</i>	Red Tree-frog	455
<i>Neobatrachus aquilonius</i>	Northern Burrowing Frog	94
<i>Neobatrachus centralis</i>	Trilling Frog	123
<i>Neobatrachus sutor</i>	Shoemaker Frog	63
<i>Notaden nichollsi</i>	Desert Spadefoot Toad	230
<i>Uperoleia micromeles</i>	Tanami Toadlet	30

There are several identification guides to frogs including: *Frogs of the Northern Territory* by Tyler and Davies (1986) and *Reptiles and Amphibians of Australia* by Cogger (1992).

12.2 Mammals

Of the arid NT native mammals, bats have the closest association with wetlands but their ecology has not been systematically studied in arid Australia. Some species may require surface water for drinking. If

this is true then prior to the creation of stock watering points over the past 100 years they would have been reliant on the scarce permanent waterholes during droughts. Certainly the abundance of flying insects over wetlands is important as a food source for bats and the episodic inundation of temporary wetlands may accordingly be important in maintaining populations by creating breeding pulses. Bat sampling in the Finke Floodout forest in 2001, following the cessation of waters after large river flows in 2000, recorded most of the species known for central Australia as present there (D. Matthews pers. comm.).

The following list of bat species in the arid NT was created from pre-existing distribution records in the NT Fauna Atlas from across the arid NT and not just from wetlands. Two useful identification guides are *A Field Guide to bats of the Northern Territory* by Thomson (1989) and *Australian Bats* by Churchill (1998).

Table 33. Bat species known from the arid NT

Scientific Name	Common Name	No. of arid NT records in NT Fauna Atlas
<i>Chaerophon jobensis</i>	Northern Freetail-bat	1
<i>Chalinolobus gouldii</i>	Gould's Wattled Bat	299
<i>Chalinolobus morio</i>	Chocolate Wattled Bat	196
<i>Hipposideros ater</i>	Dusky Horseshoe-bat	?4
<i>Macroderma gigas</i>	Ghost Bat	?38
<i>Mormopterus planiceps</i>	Southern Freetail-bat	86
<i>Nyctinomus australis</i>	White-striped Freetail-bat	59
<i>Nyctophilus geoffroyi</i>	Lesser Long-eared Bat	115
<i>Pteropus scapulatus</i>	Little Red Flying-fox	5
<i>Saccolaimus flaviventris</i>	Yellow-bellied Sheath-tail Bat	26
<i>Scotorepens balstoni</i>	Inland Broad-nosed Bat	140
<i>Scotorepens greyii</i>	Little Broad-nosed Bat	15
<i>Taphozous hilli</i>	Hill's Sheath-tail-Bat	64
<i>Vespadelus baverstocki</i>	Inland Forest Eptesicus	36
<i>Vespadelus finlaysoni</i>	Finlayson's Cave Bat	77
<i>Vespadelus pumilus</i>	Eastern Forest Bat	120
<i>Vespadelus vulturnus</i>	Little Forest Eptesicus	?8

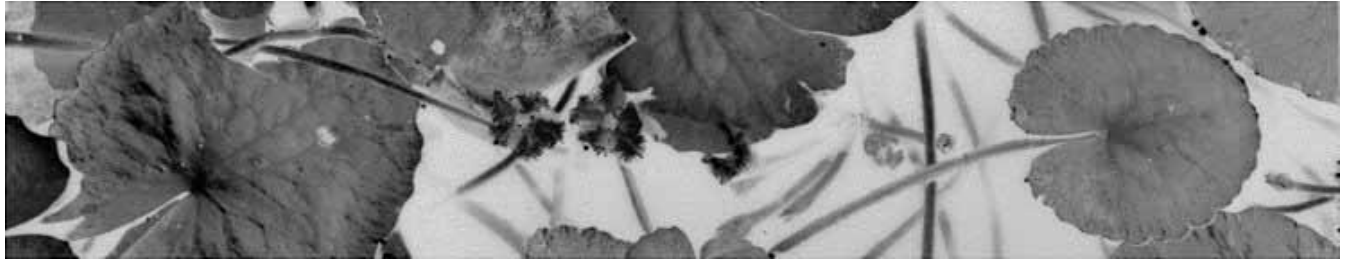
Numbers of records are preceded by a question mark for species which are considered unlikely to occur in the study area.

None of Australia's three species of mammal that rely on wetlands occurs in the arid NT. The Platypus (*Ornithorhynchus anatinus*), a monotreme, is restricted to streams of the east coast, south-east coast and Tasmania. The False Water-rat (*Xeromys myoides*) is only known from coastal areas in the Top End of the NT and Queensland. In contrast, the Water Rat (*Hydromys chrysogaster*) is widespread, occurring more extensively in the Top End of the NT and from quite close to the arid NT in north-east South Australia and western Queensland (Olsen 1995 in *The Mammals of Australia*), including the Coongie Lakes area of South Australia (Reid & Puckridge 1990). Consequently, it might be possible that it could occur in the arid NT, most probably at long-term waterholes along the Georgina River. It is almost entirely restricted to permanent waterbodies, occasionally being a vagrant of temporary waters (Olsen 1995). It is highly unlikely to occur in the lower Finke River under the current climate, due to the lack of long-term waterholes and the isolation by the Simpson Desert dunefields.

12.3 Reptiles

There are no species of reptiles that are only found in the vicinity of wet areas although wetlands may be of occasional importance in generating food sources. Some snakes and lizards may experience breeding pulses in wetland areas following inundation events, in the same way as bats; and some snake species are known to hunt frogs along river beds following flows.

There are no native turtles (or tortoises) in the arid NT. Several species occur on the margins of the Australian arid zone. To the north of the arid NT are two species: Northern Snappy Turtle (*Elseya dentata*) and the Northern Snake-necked Turtle (*Chelodina rugosa*). There are various species to the east and south-east, notably in the Murray-Darling River system. One species, *Emydura krefftii*, extends from coastal Queensland into the arid interior (interpreted from the distribution map in Cogger 1992). A species of uncertain taxonomy, *Emydura sp.*, occurs in the north-east of South Australia (Tyler *et al.* 1990), including Coongie Lakes, which Reid and Puckridge (1990) refer to as the Cooper Creek short-necked tortoise.



13. Distribution and Mapping

Scope and Summary of Wetland Mapping Activities

Improving the mapping of wetlands was a major component of the inventory. The first step was reviewing pre-existing mapped information; principally 1:250,000 topographic maps. This included assessing the categories and or symbols used to depict wetlands and their relationship to our broad wetland types. Pre-existing mapping was evaluated in the field where possible. This included recording additional wetlands to those that were already mapped, identifying errors of ‘commission’ where an area is depicted as a wetland on a map but should not have been, and assessing how well the mapping represents the wetland type(s) and extent. Most of the field work was ground-based, but there was some aerial survey. This comprised of two dedicated wetland flights and also a large number of wetland observations made during a camel survey. Some pre-existing wetland location information was obtained from sources other than maps including: references in reports, herbarium specimen locations and personal communications.

New mapping of wetland areas consisted of point observations from the survey work and mapping ‘waterbody polygons’ from satellite imagery. The term ‘waterbodies’ is used here for areas that are inundated and can accordingly be discriminated using multi-spectral imagery. The term is not synonymous with ‘wetlands’ which may be dry much of the time. The remotely sensed mapping of wetland areas was systematic but not comprehensive. The limitations of this component are presented with recommendations for future work. Additional mapping work was done to depict drainage lines at various scales and to map connectivity.

Some ‘temporal mapping’ of inundation regimes was conducted using remote sensing and this is also presented in this chapter, including a comparison with the continental scale work of Roshier *et al.* (2001).

Some sources of additional mapping and information have been identified but were not incorporated due to time constraints. These are listed to facilitate their inclusion in any future wetland mapping.

The wetland mapping part of the inventory also included some review of national drainage basins which is reported in chapter 4 of this report: ‘Overview of Major Drainage Systems’.

The following is a summary of the mapping component of the inventory:

- review existing mapping sources and other sources of wetland locations;
- revising catchment boundary mapping;
- assessing the adequacy of the pre-existing mapping during field survey;
- recording the presence of previously unmapped wetlands during field survey;
- allocating observed wetlands to wetland types (where possible);
- mapping wetlands from satellite imagery;
- producing an accurate, generalised digital map of major drainage features;
- mapping connections between and extensions to drainage channels;
- analysing patterns of inundation in selected wetlands using satellite imagery.

13.1 Published and Other Pre-existing Maps

Overview

There was very little systematic mapping of wetlands of the arid NT prior to this study. Pajmans *et al.* (1985) derived density maps of very broad wetland types across Australia. They derived these from unpublished wetlands maps which they created using wetland features on the 1:250,000 scale topographic maps. Their density maps provide a broad indication of the national distribution of their broad wetland types but are quite uninformative at the more detailed scale of the arid NT.

There are published topographic maps covering parts of the arid NT at various scales, and depicting wetland features in various ways. The entire area is covered by both the 1:1 million and 1:250,000 scale topographic maps. At more detailed scales the coverage of topographic maps is very poor. Roughly 16% of the area is covered by 1:50,000 orthophoto topographic maps produced by the Australian Army and there is one published 1:100,000 scale topographic map sheet (Alice Springs 5650), produced by the national mapping agency. However, unpublished 1:100,000 scale mapping by the national mapping agency is available as raster images scanned from compilation sheets. In addition there is a published 1:100,000 scale topographic map of Uluru Kata-tjuta National Park, plus various higher resolution maps covering small areas, such as Alice Springs, produced by the Northern Territory Government. Some wetland information is also available on geology, land systems and land unit maps.

The nature of wetland information on each of these sources is discussed below. The main source of wetland extent is the 1:250,000 map series and this is discussed first. Not all information from other sources was collated due to time constraints.

The mapping component of this inventory only partly addressed the need for further wetland mapping. However, the main sources of additional information are reviewed in this chapter to provide a basis for future mapping work.

Wetland Features on 1:250,000 Scale Published Topographic Maps

There are 36 maps covering the study area in the 1:250,000 scale series. These are produced by the national mapping agency (previously AUSLIG, now GeoScience Australia), with map sheets based on a grid of latitude and longitude.

The 1:250,000 scale topographic maps are the primary source of information on wetland area and provide some basic information about wetland type. Most, but not all of the wetland information on the published maps is available in the associated digital data product.

The following wetland categories are distinguished on the 1:250,000 maps:

- drainage lines, depicted by single lines or as double lines (polygons), depending on size;
- waterholes, mostly as points but as also as solid blue shaded polygons on some maps;
- lakes, shaded differently for intermittent or mainly dry;
- dams, depicted as points or polygons depending on size and map sheet;
- swamps, depicted by shading;
- areas subject to inundation, depicted by shading without a polygon outline;
- floodouts associated with drainage lines, depicted by an outline or by shading;
- springs, depicted as points;
- comments such as ‘numerous small claypans’ indicating aggregations of features, for which the individual elements are too small to map.

The 1:250,000 topographic maps do not adequately distinguish the different wetland types for the purpose of wetland inventory. Furthermore, many wetland types are not mapped at all. The mapping of wetland features is not entirely consistent between map sheets. Some sheets show drainage to a higher level of resolution than others; notably the Hermannsburg 1:250,000 sheet shows a drainage density that is equivalent to the 1:100,000 scale mapping and is inconsistent with adjacent 1:250,000 scale sheets. This

contrast occurs on both the hardcopy published maps and in the published digital coverage. Some maps depict waterholes by dark blue shading, where as most sheets only depict waterholes as points. The mapping of waterholes is also inconsistent with regard to naming and persistence. Some relatively minor and short lasting waterholes are mapped and named, while other more persistent waterholes are not named and in some cases they are not shown at all.

In his 'Review of Wetland Inventory Information in Oceania', Watkins (undated) notes that a scale of 1:250,000 is too general to detect many wetlands. This is certainly true for the arid NT. There are many smaller springs, swamps and claypans which are not shown on the 1:250,000 topographic maps.

1:250,000 Digital Data – Vector and Raster

The AUSLIG Geodata product, based on the 1:250,000 mapping series, provided the foundation digital wetland mapping data as points, lines and polygons. The polygon layer is the most important for indicating the size and extent of wetlands. The explanatory notes with the digital data product describe the following for the data:

'This is a polygon layer of waterbody area features such as lakes, swamps, land subject to inundation and watercourses sufficiently wide to be shown as polygons on the source material.'

'LAKE

A naturally occurring body of water surrounded by land. Included terms are claypan, saltpan, waterhole, pool, billabong, pond and oxbow. (Polygon)

Attributes

Perenniality

1 = Perennial: normally contains water, except in unusually dry periods

2 = Non-perennial: contains water for several months of each year

Name

Unique Feature Identifier

Data Quality Pointer

Selection Criteria

To obtain a consistent classification, perenniality is as defined by SYMBAS, Annex B, Chapter 7 Guide to Classification of Inland Water Features.

LAND SUBJECT TO INUNDATION

Low-lying land usually adjacent to watercourse or waterbody features, which is regularly covered with flood water for short periods either annually or during at least one year in ten. (Polygon)' (Geodata Documentation)

Not all the wetland features that are depicted on the published maps are available as off-the-shelf digital data. Some areas marked as floodouts are not available digitally and good examples of this are illustrated with maps in appendix 2. The task of systematically identifying and digitising these 'extra' features from the topographic maps is not huge, but never the less, was not undertaken in our inventory. One example that we did digitise is the 'Ancient Watercourse' which is part of the Sandover River floodout on the Avon Downs map sheet.

The 1:250,000 scale topographic maps are also commercially available as raster images (from Geoimage Inc.) and these were also used in the inventory for on-screen map investigation.

The tables below summarise the number of line and polygon features and their coded type (feature code). It is important to note that the 'lake' feature includes riverine waterholes. A process of overlay with the drainage lines and visual inspection would allow these to be separately attributed by someone with a good knowledge of the arid zone environments.

Table 34. Summary of Polygons by Feature Code (Geodata 1:250,000)

Featue Code	No. of Polygons	Area km ²
'lake'	4,996	3,330
'swamp'	19	208
'sub_to_inund'	34	528

'reservoir'	4	0.3
'watercours_a'	550	1,011
'w_body_void' (islands in lakes and watercourses)	905	512

Table 35. Summary of Drainage Lines by Feature Code (Geodata 1:250,000)

Featue Code	No. of Arcs	Length in km
'canal'	2	7
'connector'	6,982	6,662
'watercours_l'	111,608	139,436

The digital drainage line data include 404 watercourse names, not all unique to a particular drainage system.

The connectors are lines that continue depiction of a drainage line 'through' a river section that is mapped as a polygon feature. The 'canal' features are long drains adjacent to roads in the Wauchope Hotel area.

The Geodata product also includes a point theme of localities but none are waterholes.

Another digital dataset of points from topographic maps is available from AUSLIG/Geoscience Australia, called the Gazateer. A quick inspection shows that this includes a great many wetland features. The many waterholes and lakes may be mostly included in the polygon data above. The Gazateer also includes 19 swamps, 45 springs and 4 claypans for the study area. Outlines of some of the swamps and claypans are included in the polygon data, but not all with names. Therefore, some additional information on wetland location and name can be obtained from the Gazateer.

Wetland Features on 1:1 Million Scale Published Topographic Maps

There are four 1:1 million maps for the study area. These maps were used mainly for navigation and give an excellent overview of the study area. They are generally too coarse for mapping most wetland features. However, in some cases the 1:1 million maps depict wetlands that are not shown on 1:250,000 maps. For example, the Lake Mackay 1:1 million map shows extensive swamps to the north of Mt Redvers and Mt Morris that are not depicted on the 1:250,000 map of the same name. The 1:250,000 map shows a relatively small area of lakes and drainage channels. Satellite imagery from a very wet period indicates that the area is prone to more extensive inundation. The task of digitising a polygon of the extensive 'swamp' from the 1:1 million mapping has not been undertaken due to time constraints. Some of the swamp area is included in our revised wetland mapping through the automated mapping of waterbodies from satellite imagery.

Wetland Features on 1:100,000 Topographic Maps

Although there is a published topographic paper map for only one standard 1:100,000 map sheet, the entire study area was mapped from aerial photographs in the 1970's as part of the national 1:100,000 scale mapping project (Bob Kennard, pers. comm.). Most areas were mapped from black and white photographs at a scale of about 1:80,000 and then compiled at 1:100,000. This mapping was the basis for many elements of the present 1:250,000 mapping series. Some line features on some map sheets have been digitised from compilation (pre-publication) material. However, for most of 1:100,000 maps over the study area there has been no line digitising.

All the map sheets of the study area are available as scanned raster images of the 1:100,000 scale compilation material (from Geoimage Pty Ltd). These raster maps were obtained and used in various ways in the inventory. Some of the maps were plotted and used for navigation in the field. Also, some of the raster 1:100,000 maps were used in on screen checking of some of the remotely sensed waterbodies.

A limited inspection indicates that the 1:100,000 maps generally show the same wetland boundaries as the 1:250,000 maps. It was not possible to rigorously check all the raster 1:100,000 maps (216) for

additional wetland features. This task would be relatively straight forward but would probably produce relatively little data for the time involved.

Wetland Features on Army 1:50,000 Orthophoto Map

Roughly 16% of the area is covered by 1:50,000 orthophoto topographic maps produced by the Australian Army; 139 map sheets out of a possible 864.

Some of the 1:50,000 orthophoto maps show wetland features that are not on the 1:250,000 maps. For example, the Laughlin 5751-2 sheet shows two springs, one of which has a significant outlying population of the endemic wetland plant *Callistemon pauciflorus*. On some sheets there is some extra information from contours around drainage depressions, however, these cannot be treated as wetlands without other corroborating information. In some cases, the contrast in the orthophoto indicates a possible claypan or salt lake. In most cases there was insufficient time to pursue the usefulness of this information in this inventory and some value may be obtained from it in future more detailed wetland mapping exercises. The extent of these maps is shown in figure 14.

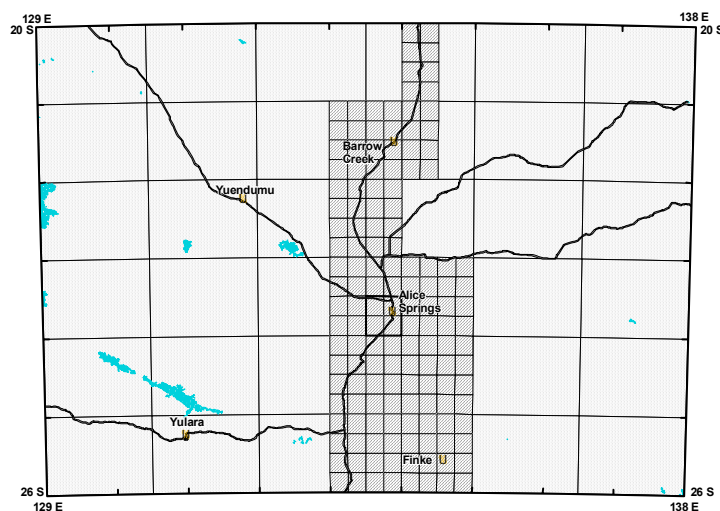


Figure 14. Extent of 1:50,000 Orthophotomaps

Geology Maps

Geological mapping at 1:250,000 scale is available over the whole study area; undertaken by the Bureau of Mineral Resources (now Geosciences Australia) and the Northern Territory Geological Service. There are also a few finer scale published geological maps; mostly at a scale of 1:100,000 and based on areas of special interest rather than standard map sheets.

In general the depiction of waterbodies and drainage on geology maps is the same as (or less than) the corresponding topographic maps but occasionally extra information is provided. For example the Hermannsburg 5450 1:100,000 geology map (preliminary edition of 1975) shows the location of Mount Giles Spring which is not shown elsewhere. Occasionally the 1:250,000 geology maps show additional swamps. Time did not permit for systematic identification and collation of additional waterbodies shown on geology maps. This task would be relatively straight forward but would probably produce relatively little data for the time involved.

The geological sheets could be used to provide some information on wetland type. For example, a lake shown as evaporites on the geology map can be translated to 'salt lake' for attributing wetland type. Other wetland areas may be shown as alluvium on the geology map, indicating that they are not salt lakes. However, this would not allow for distinguishing swamps (vegetated) from pans (unvegetated).

Land Systems and Land Unit Mapping

Approximately two thirds (61%) of the study area is covered by the original CSIRO land system mapping of Perry (1962). That land system mapping was the foundation for much subsequent mapping and survey work, including delineation of the IBRA bioregions.

Subsequently, finer scale land unit mapping and some revision of the land system mapping has been undertaken by the NT Government. Approximately 7% of the study area has been mapped at 1:250,000 (land systems), 14% at 1:100,000 (land units) and 1% at 1:25,000. Most of the land unit mapping has been on pastoral leases although there is also some on national parks, as described by Pitts and Matthews (2000). The coverage of the study area by land system and land unit mapping is shown in figure 15.

The land unit mapping is generally more useful for delineating wetlands than the land system mapping. At the scale of land systems mapping, few if any individual wetlands are delineated. In contrast, smaller swamps and lakes are often delineated in landunit mapping, which is often based on 1:50,000 scale photography (even when compiled or presented at 1:100,000).

Many land unit maps were inspected for wetland information to assess their value for wetland inventory. Some of these provide good information on wetland boundaries and type. For example the land unit map and report for Neutral Junction pastoral lease (Lehman and Edgoose 1996) distinguish various landunits that equate directly to wetlands, for example unit 7.8 is claypans and 7.9 is swamps. The land unit map of Tarlton Downs Station delineates a wetland area that includes elements of claypan and Bluebush swamp, that is not shown on the topographic map. Another example is Felix Springs on the south side of Mount Olga. It is marked and named on 1:50,000 land unit map (Hooper *et al.* 1973) but not on AUSLIG 1:100,000 topographic map (c. 1990).

There was insufficient time to allow wetlands that were identified from land unit maps to be included in our revised wetland GIS dataset. Some of the land unit maps already exist as digital GIS data and there is an ongoing program of establishing all the landunit maps as accessible GIS datasets. This should allow any future wetland inventory to incorporate wetland outlines from land unit mapping.

The following land unit maps and associated reports were examined, which is about half of those available for the inventory area:

- Amburla Pastoral Lease;
- Annitowa Pastoral Lease;
- Andado Pastoral Lease (draft);
- Ayers Rock
- Argadargada Pastoral Lease;
- Lucy Creek Pastoral Lease;
- Lilla Creek Pastoral Lease (draft);
- Murray Downs Pastoral Lease;
- Narwietooma Pastoral Lease;
- Neutral Junction Pastoral Lease;
- New Crown Pastoral Lease;
- Tarlton Downs Pastoral Lease;
- Watarrka.

The reports associated with land system and land unit mapping also provide useful information on the morphology, vegetation, hydrology and geomorphology of some wetland types. For example Perry (1962) provides a useful insight to the saline lake systems associated with Karinga Creek. Another good example is from the Neutral Junction land unit report (Lehman and Edgoose 1996). This provides useful information for interpreting bare flats adjacent to Taylor Creek where it passes the Osborne Range, such that they can be classified as flood-prone flats rather than claypans. It is possible that there is a useful correlation between some land systems and the incidence of some wetland types, however time did not permit this line of investigation to be followed. A possible method would be to map features such as claypans in a test area using aerial photography and then estimate their abundance in other areas of the same land system.

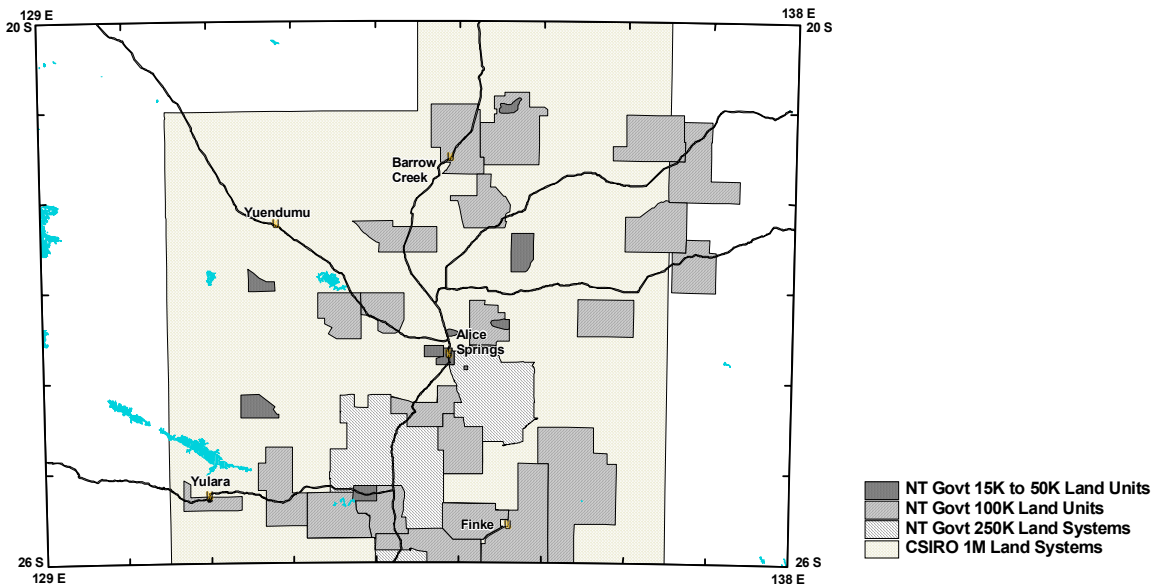


Figure 15. Extent of land system and land unit mapping in 2002

Other Maps

A very important historical map of waters in the south west of the MacDonnell Ranges Bioregion shows many wetland features which are not recorded elsewhere:

Sketch map of the James Ranges, Central Australia by Bryan Bowman and P.A. Scherer, 1948
(scale ca. 1:31680; extent ca. 131° 30' - 133° 00' E and 23° 59' - 24° 40' S; size 71 x 116 cm)

Brian Bowman was manager of the pastoral lease that included the Watarrka area, for several decades from about the 1930s. He later managed the Glenn Helen Lease. There may not be many copies left of this map. There is an original in the National Library in Canberra and on the Wall of Jim's Place Roadhouse south of Alice Springs. Graham Ride provided a photocopy of a photocopy for our inventory. Graham also has a list of corrections to some of the original names and some other ancillary information about some of the water features shown. It is intended to capture the location information into our wetlands database but this has not yet been done. Much of the country mapped is remote and seldom visited now that people do not walk or ride on horse through the country for their livelihoods. Very few people may retain knowledge of some of the mapped wetland features which include springs, rockholes, waterholes, soakages and swamps.

Graham Ride of the NT Department of Planning Infrastructure and Environment has mapped ground water resources and some surface water resources for various pastoral leases and land trusts in the Alice Springs district.

Some additional wetland location data can be found on hydrogeology maps for the arid NT. Some of these were inspected for this purpose but not systematically across the study area. As an example, two additional waterholes are marked on the *Hydrogeological Map Southeastern Georgina basin* (1:500K, M.A. Randall 1978) that are not on the current 1:250,000 topographic map series. The first is Woonunajilla WH which corresponds to one of our wetlands survey sites and is a swamp. The second is Alanjeer WH which is at approximately the same location as Alanjeer Bore as marked on the Hay River SF5316 topographic map.

The Western Waters Study (Wischusen 1998) included maps at 1:250,000 which show some waterholes, springs and seepages in addition to those on the published topographic maps. Another example is the map of *Hydrogeology of the Lake Amadeus – Ayers rock Region* (1988). This is a composite of maps of various scales and has an accompanying report by Jacobsen *et al.* (1989).

Aerial Photographs

Aerial photographs were used in some of the field work and to aid in the description of a few wetlands. For such a large area it was not possible to systematically map wetlands from aerial photographs. However, aerial photographs should be used in the future for mapping individual important wetlands or areas of particular interest.

13.2 Non-Map Sources of Wetland Location Data

Written Reports

Various information on wetland type and location was collated from written reports and is presented in Volume 2 of this report. Due to time constraints, it is likely that some location information remains to be collated. A brief summary of the sources and types of information is presented below.

Biological Survey Reports

The most substantial source of written information about specific wetlands for the inventory area is the collection of reports on biological surveys undertaken by the Wildlife Research group of the Conservation Commission of the NT (now the Biodiversity Conservation unit of the Parks and Wildlife Service of the NT, Department of Natural Resources, Environment and the Arts). Most of these are internal reports with few copies. The Arid Zone Research Institute library has a full set. A few are published as technical memoranda. The majority of these surveys date from 1980 to the late 1990s. Those that were found most useful for the wetlands inventory are listed below in chronological order. In many cases the reports do not provide coordinates for specific wetlands but provide information on the presence of unmapped wetlands or the character (and type) of mapped wetlands. In addition, many of the reports were invaluable in developing a general understanding of wetland systems of various areas and in developing field survey itineraries.

- Aerial and ground surveys in the Tanami Desert* (Johnson et al. 1980)
- Fauna and flora survey of the north-western Tanami Desert* (Gibson et al. 1981)
- A biological survey of the Kings Canyon area* (Latz et al. 1981)
- A botanical survey of Illawilla Creek and surrounding areas of Henbury Station* (Latz 1982)
- A biological survey of the Dulcie Range, Northern Territory* (Latz and Langford 1983)
- A preliminary biological survey of portions of the McLaren Creek Pastoral Lease* (Fleming et al. 1983)
- A Resource Survey of the Davenport and Murchison Ranges in the Tennant Creek District* (Johnson et al. 1984)
- Wildlife Survey of the Hay River and Plenty River regions of the Simpson Desert* (Gibson et al. 1985a)
- A biological survey of the Tanami Desert in the Northern Territory* (Gibson et al. 1986)
- Botanical significance of the Lake Surprise Dunefield Area* (Latz 1988)
- A resource survey of the Dulcie Ranges, Northern Territory* (Gibson et al. 1989)
- Botanical significance of the Lake Surprise Dunefield Area - part II* (Latz 1989)
- A resource survey of northern Loves Creek pastoral lease and Ruby Gap Nature Park* (Gibson et al. 1992)
- Flora and fauna survey of the Wakaya Desert* (Gibson et al. 1994)
- Ranger training/flora and fauna survey of the Toko Ranges* (Fogarty et al. 1995)

Hydrogeology Reports

Various reports were consulted with respect to the influence of groundwater on wetlands in the study area. Many of these also contained information on wetland location. A few examples are given here.

The hydrogeology report of the Western Waters Study (Wisconsin 1998) is an example of the various groundwater studies by the Northern Territory Government and the Australian Geological Survey Organisation (now GeoScience Australia). The emphasis is typically on documenting the geology and hydrology of ground water systems; however, some very useful information is provided on surface waters and their connection with groundwater. Wisconsin (1998) gives a one page summary of groundwaters, including 13 springs in the Treuer Range, collectively known as Pikilyi by Walpiri Aboriginal people. He also mentions Illpili spring in the Ehrenberg Range and Putardi spring at the western base of Mt Putardi, along with photographs. No location details are given and this complicates the task of storing information on a GIS database. A precursor to a full GIS database could be to collate such information in a non-spatial database. We have collated information in Volume 2 of this report, that will be the basis for such a database. Only two of the 13 Pikilyi springs are shown on the Mt Doreen 1:250,000 topographic map sheet. Putardi spring is shown on the Mt Liebig map, and a feature called Illpilla Soak on the Mount Rennie map may be the same place as Illpilli spring. Wisconsin (1998) does give some useful information on attributes such as flow volume and permanence, but this is opportunistic as it is not a core element of that work. For example, Vaughan Springs (one of the Pikilyi 13) is regarded as permanent despite substantial variations in output. A photo of Putardi shows it to be a surface spring but permanence and flow variation are not discussed. A photo of Illpilli shows a dry creek and the text indicates that typically water is obtained by digging, as for a soak, but that the reputed permanency of supply indicates a subsurface seepage spring.

Another interesting example is the paper by Jacobson (1996) reviewing ground water systems of the Amadeus Basin. Jacobson (in Morton and Mulvaney 1996, 259) notes the existence of springs in Lake Amadeus but does not give locations:

‘several springs in the Lake bed discharge ‘fresher’ groundwater (about 90 g/l TDS) under pressure, through the brine pool. One mound spring, several metres high, encrusted with carbonate has been observed at the eastern end of Lake Amadeus.’

Aboriginal Information on Location and Character of Individual Wetlands

The Western Waters Study was unusual in the extent to which Aboriginal water knowledge and issues were investigated. These are reported by Toyne (Toyne 1995) in a separate report to the hydrogeology work. About 400 Walpiri surface water sites are named and classified in Appendix 1. The information is based on consultations with the traditional owners. Not all of the waters equate to wetlands as defined for this inventory. Soaks are typically at the margin of the definition. Whilst they may potentially support biota that are directly dependent on the saturated soils, analogous to the hyporheic zone of rivers, such biota are not known.

It is likely that there would be cultural difficulties in obtaining and storing detailed location information for many of these sites. Such information is sometimes part of ‘sacred-secret’ information and may be complicated by law restricting access to a site to men only or women only.

There is no doubt that the vast resource of traditional knowledge of waters could greatly contribute to wetland inventory. Our inventory was not set up in a way that allowed us to pursue this. Typically a great deal of time is required to work with traditional owners and develop trusting relationships in order to develop ways of sharing and documenting traditional ecological knowledge. Language barriers can be significant and such programs are best undertaken where some of the investigators are fluent in both English and the relevant Aboriginal language, or with interpreters.

Herbarium Specimen Records

A GIS points coverage was created from the specimen records of the NT Herbarium (Holtze) and linked to the list of wetland plants (reported in chapter 9) to assist in identifying additional wetlands. This approach was applied at a broad scale (of all of the Northern Territory) by Storrs and Finlayson (1997).

However, the scale of presentation of their maps does not allow assessment of the utility of this approach. The task of systematically using records of indicator plants to identify wetlands was too large to undertake in our inventory of the arid NT.

We subset the data to only include wetland plant specimens collected by Peter Latz (4555 specimens of taxa with higher fidelity to wetlands than drylands). By displaying the locations of these on a GIS computer screen, Peter Latz was able to recollect additional information about the wetlands for some of these (84 locations). The comparison with existing 1:250,000 mapping is not complete but many of these records provide information on the wetland type of wetlands already mapped on the 1:250,000 topographic maps (at least 28). Some identified additional wetlands (at least 24).

This approach could be extended in various ways. Plant records could be colour coded according to the fidelity of the species to wetland habitats and displayed against other wetland location data. Another use of herbarium specimen data is to search the comments and location descriptions for key wetland words such as 'waterhole'. This was done in developing the list of wetland plant species but has not been applied to mapping wetland locations.

Personal Communications

Peter Latz provided a great deal of advice on wetland environments and important places to look at in the surveys, including the Newhaven lakes and the Elkedra floodout, as well as information associated with plant collection locations. We also obtained information from other people on wetland location and type/character. Graham Ride was a key contributor of information of this sort and it was not possible to collate all his knowledge of spring locations within the timeframe of our inventory. He is also collating historical and other information on springs and other natural surface waters in the arid NT (pers. comm.).

Dennis Matthews and Darren Schunke provided information for the Palm Valley area and Darren provided information for the Watarrka area. Several pastoralists provided important information on the location and character of wetlands.

NT Government Water Resources Database

A database of stream flow gauging and water quality is maintained by the Natural Resources branch of the NT Government Department of Natural Resources, Environment and the Arts. Known as HYDSYS it includes water chemistry data from springs and waterholes as well as from bores. This source of location data has not yet been investigated for mapping wetlands.

Other Sources

A few wetlands were added to volume 2 after seeing slides of them in various slide collections.

A few springs and soaks were collated from information on the Larapinta Trail brochures, such as Mint Bush Spring north of Birthday Waterhole.

Bayly (2001) reports invertebrate dynamics in non-channel rockhole in the Papunya area but does not give exact coordinates. There are few such references to specific wetlands in journal papers, apart from the large well known waterholes.

13.3 Inventory Survey Data

Wetlands Survey Ground Sites

The ground survey data provide a basis for attributing wetland polygons with wetland type; however, this is yet to be done.

Several sites were surveyed that were mapped as a wetland but were deemed not to be wetland during our field survey, or were only at the margin of the definition of a wetland. Two examples are presented here.

Thring Swamp is delineated on the Bonney Well 1:250,000 map sheet as a large area subject to inundation. Its size makes it stand out on the digital Geodata coverage, and the inclusion of the term 'swamp' in the name indicates that it may be a significant wetland. However, it is mapped as 'subject to inundation', not swamp, and field survey confirms this, indicating that it does not typically hold water for long and is best classified as a flood prone flat rather than a basin. Although named on the published map, the name is not included in the digital Geodata.

The second example is a small basin mapped as a lake on the Finke 1:250,000 map sheet, at the eastern end of the Karinga Creek chain of lakes. This site was deemed to not be a wetland. It was a small grassy basin and probably subject to only very brief inundation, based on the landform and the presence of some Cottonbush (*Maireana aphylla*). The substrate and the vegetation both indicate that water does not sit long on the surface and neither is the soil saturated for any significant length of time. There was a well developed ground layer including grasses (notably *Enneapogon cylindricus* and *E. avenaceus*) and forbs.

Wetlands Aerial Survey Sites

Opportunistic information on wetland location and type was obtained on the reconnaissance flight in July 2000. Some of that information is incorporated into volume 2 of this report. The systematic data obtained during the aerial camel survey was much more extensive and is discussed below.

Camel Survey Wetland Location Data

An aerial survey of feral camels was conducted in the southern NT during the time of the wetlands inventory. In addition to recording feral animal observations, the camel survey observers recorded the occurrence of wetlands. The methods and results of this component of the wetlands survey are presented below. Our reporting of the methods draws on the camel survey report by Edwards *et al.* (2004).

The camel survey was conducted from 20 August to 12 October 2001. Transects were flown in an east-west direction, at an average speed of 185 km/h; average height of 61m above ground and with a between transect distance of 11.1km. Observations were recorded in hand-held computers with position coordinates from a global positioning system. Three observers were present on each flight, one on the port side of aircraft operating alone and two on the starboard side of aircraft operating as a tandem team. The formal transects were 200m wide strips on either side of the aircraft, defined by pairs of fibreglass rods fixed to the wings. A limited number of the wetland observations may have also come from the central 300m wide strip 'under' the plane, or from beyond the 200m formal observation strips (Keith Saalfeld pers. comm.). Thus the survey swathe for wetlands was potentially up to roughly 900 - 1000m wide, however for most of the survey it was fixed at the combined formal transect swath of 400m. The total distance of flight transects was approximately 24000 kilometres, so the actual area systematically surveyed for wetlands was around 9,600km². The total survey area, sampled at an intensity of 3.6% was 259,129km² (Edwards *et al.* 2004) which is almost half (42%) of the arid NT wetland inventory area.

A simple and broad classification of wetland types was devised for use in the camel survey, by Angus Duguid and Keith Saalfeld. The categories were based on the a priori wetland classification used in the wetlands ground surveys and took into account experiences from much of the wetlands ground survey and the aerial reconnaissance in 2000 (one flight). The categories were designed for ease of use such that recording wetland observations would not detract from recording feral animal information. The categories were also devised quite rapidly and with no opportunity for field testing prior to the survey. Two of the data 'fields' set up for recording feral animal information were extended for recording wetland information. The 'species' field was used to distinguish wetland specific observations from animal observations. The 'habitat' field was used to record broad wetland type. In some cases, animal observations were recorded in wetland habitats. Any area of open water was recorded as a lake. This incorporated salt lakes, swamps where the vegetation was submerged and claypans, since these could not be distinguished from each other from the air. Basins that were dry (or mainly dry) and free of vegetation were recorded as claypan/salt lake. Not all salt lakes have an obvious white (e.g. sodium-chloride) crust and so distinguishing salt lakes from claypans could not be done reliably from the air. It was decided not

to attempt to distinguish other wetland categories on presence or absence of inundation in order to keep the number of categories small. The presence of fringing shrubs or trees was not recorded and did not influence the choice of wetland category.

The wetland ‘habitat’ categories initially devised are as follows, with definitions that have been modified post-survey:

Lake - inundated area, any size, little/no emergent vegetation;

Claypan/Salt Lake – dry; little/no emergent vegetation;

Grassy Swamp - inundated or dry, small to large swamp, emergent grass (and possibly shrubs);

Swamp - inundated or dry, small to large swamp with emergent shrubs;

Drainage - inundated or dry, creek or river, vegetated;

Wooded Swamp - inundated or dry, woodland, basin or linear along drainage lines/

An additional category was created during the survey :

Grass Lake - inundated grass land (judged to be not normally inundated), typically inter-dune areas;

Also, a combination category was recorded in the survey; species = wetland & habitat = sandplain. This was probably a different way of recording areas judged to be infrequently inundated, similar to Grass Lake.

Table 36. Numbers of wetland observations during camel survey, by category.

'Species' Field	'Habitat' Field	count
Open Basins (& some shrubby basins)		
Wetland	Lake	381
Bilby Burrow	Lake	7
Bilby Sign	Lake	6
	(sub total – lakes)	(394)
Wetland	Clay Pan/Salt Lake	951
Wetland	Grassy Swamp	326
Wetland	Grass Lake	101
Wetland	Sand Plain	11
	Total - Open Basins	1783
Wooded Swamps (includes some drainages)		
Wetland	Wooded Swamp	343
Unknown Type		
Wetland	'No data'	2
Drainages (variably wooded)		
Bilby Burrow	Drainage	1
Bustard	Drainage	2
Camel	Drainage	27
Dingo	Drainage	5
Emu	Drainage	3
Horse	Drainage	1
Kangaroo	Drainage	12
Rabbit	Drainage	1
Rabbit Warren	Drainage	25
	Total - 'Drainage'	77
Total observations		2205

The survey personnel varied between flights, with 11 people in all. There was limited opportunity to instruct observers in interpretation of the wetland categories. At least one of three core observers was

present on each flight providing some consistency (Edwards, Clifford and Saalfeld). The interpretation of most of the categories will have varied between observers, particularly for wetlands with different zones corresponding to different broad wetland types. In particular, it is likely that the use of ‘wooded swamp’ and ‘drainage’ differed. At least some observers used ‘wooded swamp’ for tree lined drainages and ‘drainage’ for relatively treeless drainages. Since most drainage lines are reasonably well mapped on the 1:250,000 topographic maps it should be possible to distinguish wooded basins from wooded drainages (including linear wooded swamps) based on proximity to drainage lines on the topographic maps.

Note that some distinct observations in the data set may be observations of the same wetland by the different observers, or secondary observations of the same large wetland. There is no way to distinguish this from the case where two or more smaller wetlands were observed at the same location along the transect by different observers. Therefore the numbers of observations in table 36 do not equate to number of wetlands. A lower estimate of number of wetlands could be produced by grouping the data spatially. This has not yet been done. It is also possible that some wetlands may not have been recorded when the task of logging animal observations took precedence. The recording of secondary observations of a single wetland probably varied substantially between observers and with competition from animal observations (Keith Saalfeld pers. comm.).

A summary of the data is presented in table 36 above, along with the map below.

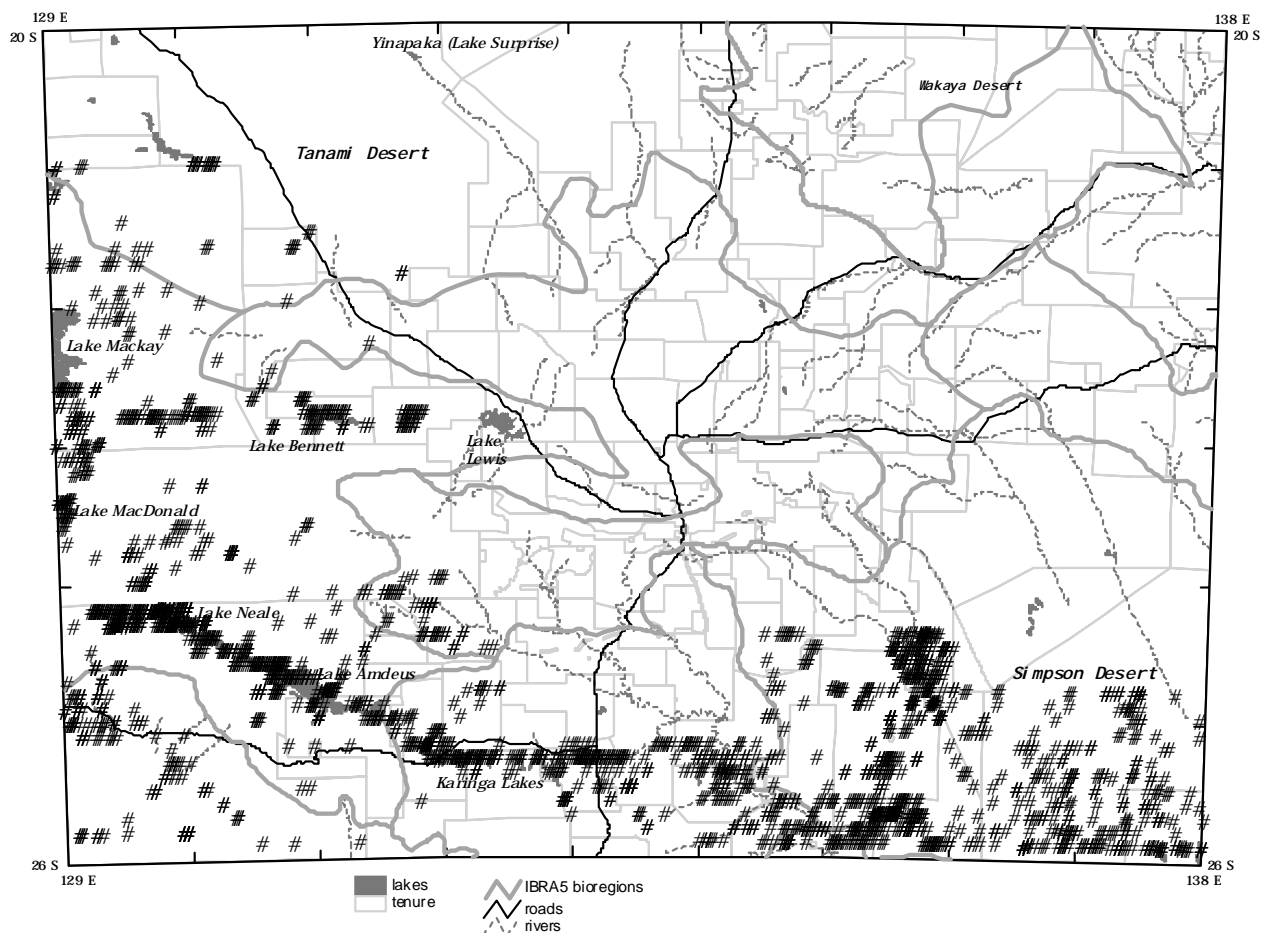


Figure 16. Wetland locations identified during the 2001 feral camel aerial survey.

The wetland data from the camel survey are very significant. They provide a set of direct observations within a systematic sampling method and compliment the systematic remote sensing work. The data currently contribute to the integrated wetland GIS database as point data of wetland ‘presence’. The data were used interactively for verifying some of the new water bodies identified using satellite imagery. Also, observations of substantial persistent water in several dune swales of the Finke River – Snake Creek

floodout resulted in an extra ground survey trip to the area. The Snake Creek inter-dune lakes were subsequently identified as a biologically important wetland complex.

The following additional uses are foreseen for the camel survey wetlands data:

- verifying satellite image based mapping of ‘waterbodies’;
- attributing mapped wetland polygons with broad wetland type;
- estimating wetland ‘density’ (by number not area); and
- providing a measure of proportion and pattern of inundation in the very large salt lakes such as Lake Amadeus.

13.4 Revision of Wetland Polygon Mapping with Remote Sensing

Overview

Remote sensing has been recognised as a valuable tool for the mapping and monitoring of wetlands since the 1970s (Pietroniro and Leconte, 2000). Our inventory coincided with two exceptionally wet years across much of the study area. Various NT Government departments identified an opportunity for natural resource studies using satellite imagery in unusually wet times. Accordingly imagery was purchased to meet various needs, which consequently presented an opportunity for remote sensing of inundation. Far more imagery was available than the project budget could have afforded.

Two forms of imagery were obtained to completely cover the entire study area. A total of 22 Landsat 7 ETM+ scenes were purchased and 12 free quicklook images obtained (figure 17). The quicklook images were downloaded from the GeoScience Australia internet site (formerly ACRES).

We tested several techniques and used two main ones to identify additional wetland areas to those mapped on 1:250,000 topographic maps. A great many additional areas of inundation were identified, even though this was not a comprehensive wetland mapping exercise. The methods, results and limitations are presented here.

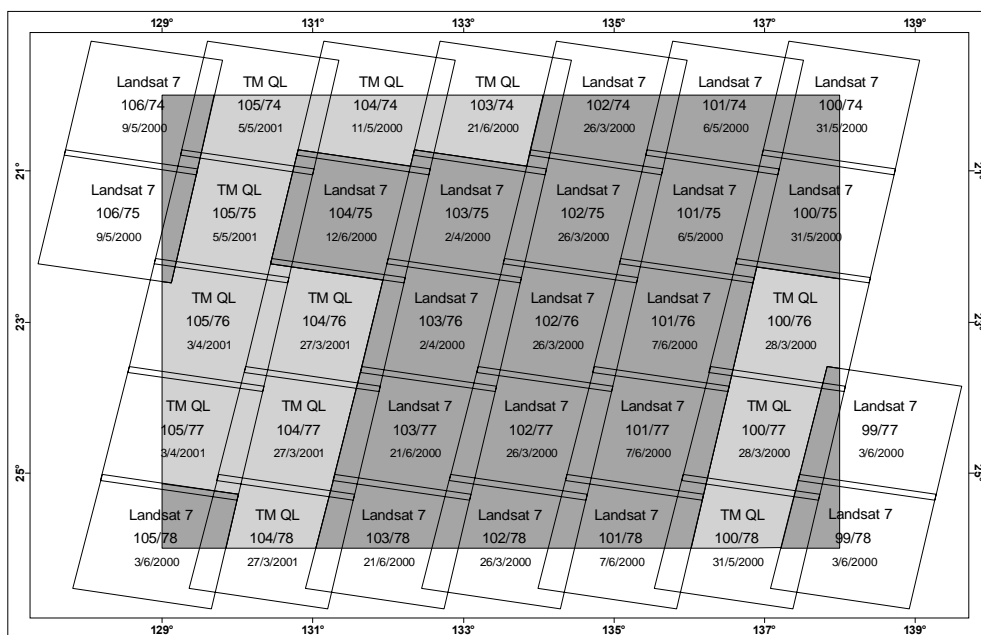


Figure 17. Satellite image type and date for automated wetland mapping.

In overlap areas between scenes, the purchased data generally took precedence, as indicated by the shading. However, in some cases wetlands were detected on quicklook scenes in the overlaps but not on the equivalent ETM+ scene.

Methods

Data

The Landsat ETM⁺ images were purchased with systematic radiometric and geometric corrections (USGS Level 1G). The images have a pixel size of 30 x 30m (spatial resolution) for the multi-spectral data, while spectral resolution is 7 channels from visible blue (TM1) to thermal infrared (TM6) with two bands in the middle infra-red range (TM5 & 7). In contrast, the quicklook images are resampled to 92 x 92m pixels and are supplied as false colour images (TM741 RGB in jpeg format) with some spectral degradation.

The images were mostly from 2000, apart from quicklook images for the western desert area. All the purchased images were from March to June 2000.

Image Preprocessing – Registration and Rectification

The purchased images were registered and spatially rectified using standard techniques by staff from various departments.

The method for registering and rectifying the purchased Landsat ETM+ images involved:

- ERMapper 4.1 software;
- cubic polygonal rectification;
- 30-50 ground control points based on AUSLIG 1:100,000 AMG projected topographic sheets;
- nearest neighbor resampling.

The method for registering and rectifying quicklook images involved:

- preprocessing using Photoshop 4 to do edge matching of adjacent scenes in a single path;
- TNTmips 5.9 software;
- separation of red, green and blue bands and saving as multi-band images;
- linear polygonal rectification of individual scenes (path images);
- 15-20 ground control points based on AUSLIG 1:100,000 AMG projected topographic sheets;
- nearest neighbour resampling.

Selection of the Image Processing Method for ETM Scenes

Three methods (algorithms) were assessed for detecting a spectral contrast between surface water and the surrounding vegetation and soils using the Landsat ETM+ images. Each of the three algorithms was applied using ERMapper 6.1.

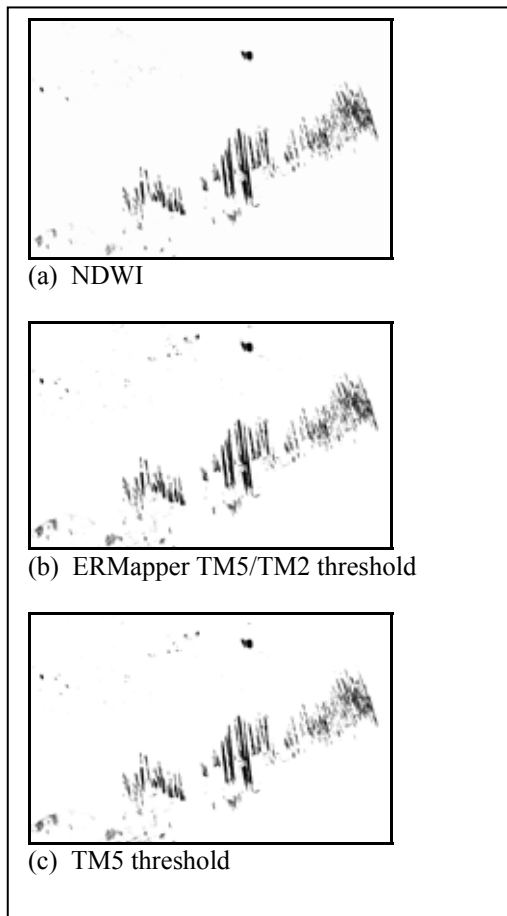
The Normalised Difference Water Index (NDWI) algorithm proposed by (McFeeters, 1996) is a band ratio index derived using principals similar to those of the Normalised Difference Vegetation Index (NDVI). Both indices use known contrasting reflection characteristics of soil, vegetation and water. The critical characteristics of the NDWI, calculated as $(\text{Green} - \text{Near Infrared}) / (\text{Green} + \text{Near Infrared}) > 0$, are minimum reflection in NIR wavelengths and maximum reflection in green wavelengths.

ERMMapper 6.1 software includes a ‘highlight water’ algorithm that was assessed as a tool to define water features. The algorithm is based on similar spectral characteristics to the NDWI, but utilising the less complex band ratio algorithm mid-infrared (TM5) / Green (TM2) < 1.

Johnston and Barson (1993) documented a method of simple density slicing of the mid-infrared (TM5) to classify wetlands, again relying on the known low reflection in mid-infrared wavelengths by water. The method was applied and a suitable threshold value selected to differentiate between water features and surrounds.

All three algorithms appear effective in highlighting areas of inundation where there is a high spectral contrast with the surrounding vegetation and soils. Figure 18 presents results for all three methods at an

area that was known to be inundated, the Snake Creek floodout. A false colour image of the same area is presented in appendix 2. However, some problems were identified with all three algorithms.



Since these algorithms all rely on low reflectance in infrared wavelengths, areas where extreme topographic variance result in shadows are highlighted as areas of possible inundation. Of greater concern was a field observation that the evaporite surfaces of playa lakes known not to be covered with water were highlighted.

The algorithms were applied to the Newhaven Station area, including Lake Bennett and surrounding wetland areas. A Landsat 7 ETM+ dataset was available for a period (7/6/2002) closely corresponding with field inspection of Lake Bennett and some surrounding wetland areas in mid-June 2002.

Field observations indicated very limited areas of water were present. In contrast, the application of the three algorithms, using the available Landsat 7 ETM+ dataset, suggested that large expanses of open water were present. In particular, the algorithms highlighted large areas of evaporite surfaces without water coverage.

The effect was not quantitatively assessed, but there are a number of characteristics of the evaporite surface that may explain the observed result: a) Poor reflection of NIR wavelengths due scattering effects off the rough surface of the evaporites; b) the mineralogy of the evaporites maybe result in poor reflectance; or c) the moisture content of the evaporite surface may be absorptive.

Figure 18. Comparison of water detection algorithms as applied to the Snake Creek floodout.

Scattering effects would impact on both green and infrared wavelengths and is not considered to be a major contributor to the observed outcome. Mineralogical studies of evaporite lake surfaces elsewhere in the region have shown halite and gypsum to be dominant minerals (Wakelin-King 1989) and the infrared spectral response would be predicted to be high reflectance (Bryant 1996). Therefore mineralogical effects are unlikely to have produced the incorrect highlighting. The most likely characteristic to have produced the low infrared reflectance is the moisture content of the evaporite surface.

Since the aim was to identify additional wetland areas to those mapped on 1:250,000 topographic maps, potential false identification of inundation on the evaporite surfaces of playa lakes was not a concern. All playa lakes have a clear expression on aerial photographs and are mapped with good accuracy on 1:250,000 maps.

The ERMMapper 6.1 ‘highlight water’ algorithm Mid-infrared (TM5) / Green (TM2) < 1 was selected as the best method for most scenes. On some scenes the TM% threshold method was found to be marginally more effective and so was used instead. The output of both methods was an image with two classes: surface water and dry land.

Image Processing Method for ‘quicklook’ Scenes

The spectral nature of the ACRES quicklook images meant that none of the three methods (discussed above) could be applied. The spectral data extracted from the quicklook false colour images only approximates the original reflectance data from TM bands 7, 4 and 1. This is because the false colour images produced by ACRES involve automated stretching of the data. A spectral contrast between waterbodies and the surrounding vegetation and soils is clearly present in TM bands 7, 4 and 1, as

illustrated for the Snake Creek floodout area in figure 19. We tested several methods to distinguish surface water in the ‘quicklook’ bands 7, 4 and 1 that were extracted from the red, green and blue components of the false colour images.

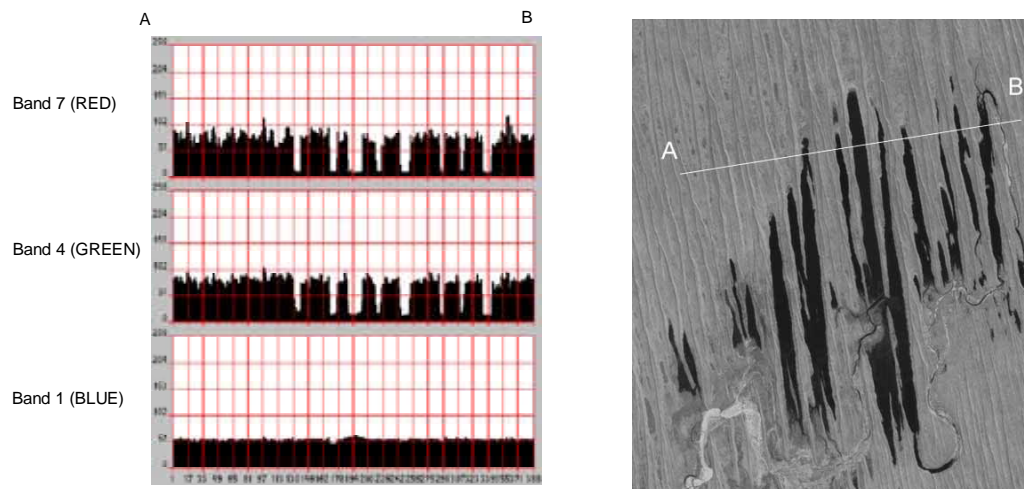


Figure 19. Spectral contrast across the Snake Creek floodout landscape

These methods were: application of thresholds to individual bands; a number of multi-band algorithms; and supervised classification. Testing was conducted on quicklook data in areas where we also had a purchased TM image. Results from applying the various methods to a quicklook image were compared with the results from applying the ‘ERMMapper highlight water algorithm’ to the corresponding ETM+ image.

Supervised classification was judged to be most effective at correctly identifying areas of inundation from Quicklook images. However, two specific errors of commission were identified. The first error was the inclusion of areas of shadow, which was also a problem encountered with the ETM+ processing. The second error of commission was the inclusion of dense interdune mulga stands in areas classified as water. The selection of mulga stands had the potential to preclude the use of quicklook imagery, but the problem was relatively easily resolved by comparison with other images from dry years. The dense mulga stands could be readily identified as vegetation on dry year images.

Training areas were selected from zones in the scene overlap between ETM+ and quicklook images and where inundation was identified from the ETM+ scene. The supervised classification of the quicklook data was conducted using the parallelepiped method. A black and white image was produced by setting the colour legend appropriately on the classified image.

Raster to vector conversion and polygon preprocessing

The resulting black and white images were converted from raster cells (or pixels) to vector polygons in ERMMapper 6.1 and exported as Arcview shapefiles. Processing as individual scenes allowed the spatial accuracy of quicklook classification to be assessed in areas of overlap and where necessary refined.

A minimum polygon size equivalent to 4 pixels was adopted. This was to reduce errors of commission in the polygon data and make the subsequent checking process manageable. For the ETM+ data, a group of four cells equates to an area of only 0.36 hectares which is near the limit that can be mapped at a scale of 1:250,000 (there are very few individual polygons smaller than 0.1 ha in the digital Geodata). The minimum polygon area for the quicklook data was 3.39 ha. Following the raster to vector conversion, all polygons below the minimum size were deleted.

In areas of overlap between adjacent TM scenes, there was a choice of which scene to use for generating the polygons of water bodies. The following factors were considered: amount of cloud and time elapsed between the last major rainfall event and the satellite overpass. Where one scene was purchased ETM+ data and the other ‘quicklook’ data, the ETM+ polygons took precedence, except where the scene date or cloud caused a wetland to be better identified from the quicklook.

The output of the processes described above was a single polygon shapefile containing areas of potential inundation.

Interactive review and verification of additional waterbodies

The polygons of areas of potential inundation were interactively reviewed and edited to verify the presence of inundation using other data sources.

Potential areas of commission induced by shadows were identified by overlaying the polygons of potential inundation on a derivative of the AUSLIG Geodata 9 second DEM (V.2). The first vertical derivative of the DEM was colour enhanced and highlighted areas of significant slope. A visual review of these areas and checking by overlay with the AUSLIG 1:100,000 raster map sheets allowed for removal of polygons corresponding with shadows.

The areas covered by quicklook images were visually reviewed by overlay with other available Landsat TM images from known dry periods. Areas of dense mulga stands, some known from field checking, were readily interpreted from this imagery and corresponding polygons removed from the mapped areas of potential inundation.

The existing 1:250,000 waterbodies coverage was overlain on the shapefile of areas of possible inundation. Areas of intersection were systematically reviewed. Where the previously mapped waterbodies correlated with areas of potential inundation, taking into account minor spatial resolution problems, the corresponding polygons within the potential inundation shapefile were deleted. In many cases 1:250,000 mapped waterbody polygons only partially covered areas of extensive inundation. In these cases the inundation polygons were clipped to only show the extension of inundation outside of mapped waterbodies.

The resultant coverage was attributed with the image data used.

Results

A total of 9387 additional waterbody polygons were identified using remote sensing; with a combined area of, an additional area of 794 square kilometres. The number and area of polygons and their source are shown for each bioregion in table 37, however, the table does not show how many of the 'new' polygons are 'new' wetlands as opposed to extensions of those that were already mapped on the 1:250,000 maps. Also, some of the new polygons are riverine water holes. This is evident for the Georgina River system and the drainages of the Davenport Ranges in figure 20.

Table 37. Numbers of mapped wetland polygons by bioregion and wetland type

Bioregion	Source	Count	% Count Increase	Area km²	% Area Increase
Burt Plain	Auslig Geodata	356		405.7	
	Landsat TM	419		16.9	
	Landsat QL	28		24.1	
	Total	803	126 %	446.8	10 %
Channel Country	Auslig Geodata	56		33.7	
	Landsat TM	383		25.0	
	Landsat QL	50		6.7	
	Total	489	773 %	65.4	94 %
Central Ranges	Auslig Geodata	200		61.6	
	Landsat TM	15		0.4	
	Landsat QL	131		24.8	
	Total	346	73 %	86.8	41 %
Davenport Murchison Ranges	Auslig Geodata	171		211.4	
	Landsat TM	998		14.9	
	Total	1169	584 %	226.3	7 %
Finke	Auslig Geodata	1035		591.0	
	Landsat TM	1239		42.1	
	Total	2274	120 %	633.0	7 %
Great Sandy Desert	Auslig Geodata	1840		2,381.0	
	Landsat TM	738		14.1	
	Landsat QL	585		149.9	
	Total	3163	72 %	2,545.0	7 %
MacDonnell Ranges	Auslig Geodata	348		139.5	
	Landsat TM	469		13.0	
	Landsat QL	44		8.5	
	Total	861	147 %	161.0	15 %
Mitchell Grass Downs	Auslig Geodata	108		174.0	
	Landsat TM	624		12.6	
	Total	732	578 %	186.6	7 %
Simpson-Strzelecki Dunefields	Auslig Geodata	586		532.1	
	Landsat TM	1646		88.3	
	Landsat QL	147		59.7	
	Total	2379	306 %	680.1	28 %
Stony Plains	Auslig Geodata	30		9.2	
	Landsat TM	488		18.6	
	Total	518	1627 %	27.8	202 %
Tanami	Auslig Geodata	931		719.3	
	Landsat TM	643		36.0	
	Landsat QL	740		238.6	
	Total	2314	149 %	993.8	38 %
Total Study Area	Auslig Geodata	5661		5258.5	
	Landsat TM	7662		281.9	
	Landsat QL	1725		512.3	
	Total	15048	166%	6052.7	15 %

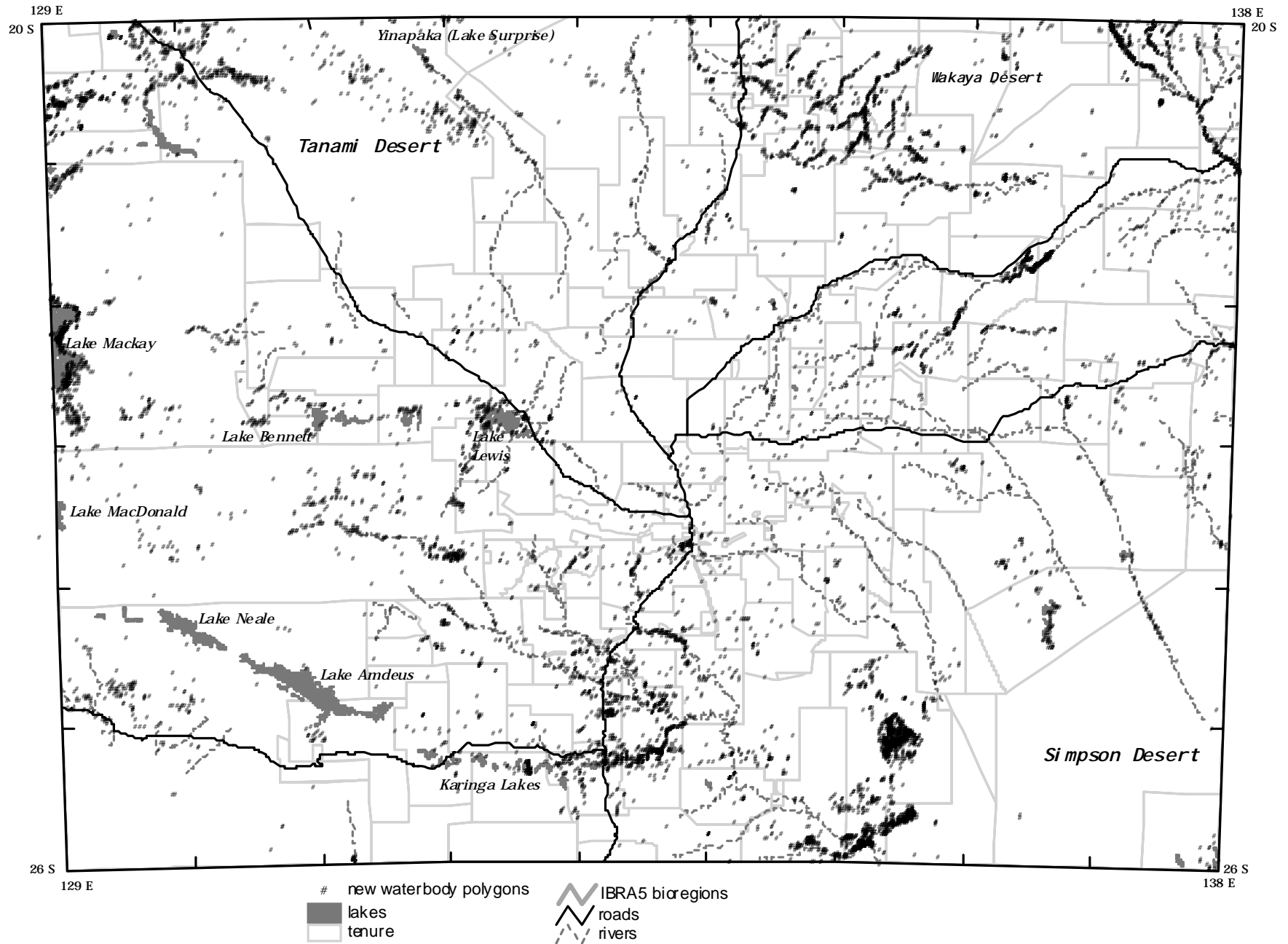


Figure 20. Map showing centre points of new waterbody polygons.

Limitations

The following issues constrained the accuracy and comprehensiveness of our mapping of inundation with remote sensing:

- availability of cloud free images;
- the use of only single date for determining inundations on each scene;
- variation in the magnitude of the 2000 rainfall events between parts of the study area;
- variation in the time elapsed between major rainfall events and the image date (both within and between scenes);
- the spatial and spectral resolution of quicklook images;
- the minimum polygon size of 4 pixels means that no new wetlands below this size were mapped;
- limited ground truthing of detected waterbodies;
- limited time/resources to apply to develop and test image analysis procedures; and
- difficulties in spectral discrimination of salt lakes from water.

Discussion

Systematic mapping of wetlands across such a large area is only possible with remote sensing and the mapping undertaken for this inventory has produced significant results. This was only possible due to: (i) extensive rains at the start of the study; (ii) the associated purchase of satellite imagery by the NT Government and (iii) a decision to allocate additional staff time to use the opportunity. The majority of time spent on the mapping (mostly by Bretan Clifford) was in addition to the ‘in kind’ contribution agreed to between the NT Government and Environment Australia. So despite some limitations in the process the outcome is an extraordinary bonus!

The 9,387 additional waterbody polygons adds enormously to pre-existing mapping of wetlands. It is not surprising that the area of increase (15%) is not proportional to the increase in the number of polygons (166%). These relative proportions indicate that after extreme rainfall events a large number of relatively small waterbodies develop. Some of these ‘new waterbodies’ may only be inundated following extreme rainfall events, but field surveys indicate that they may still be vital components in the spatial and temporal array of wetland environments.

A big improvement in accuracy and the detection of additional waterbodies could be achieved by analysing images from other dates. Some wetland types only hold water for a few weeks and these will be under-represented in our ‘new waterbodies’. Some wetlands are only filled by intense local rainfall. A good example of this is ‘new lake’ to the south west of Yinapaka (Lake Surprise). This was not identified in our image classification process despite there being extensive inundation in the Lander River floodout and in Lake Surprise at the time of the image used (June 2000). Multiple quicklook images from 2001 show a large and long lasting waterbody following heavy local rain in March 2001. This example is illustrated with colored imagery in appendix 2.

The minimum polygon size of 4 pixels could have been relaxed in areas where the presence of water was corroborated by field observations (ground survey and aerial camel survey). Although time did not permit this, the field data and archived images are available for any future, more detailed, wetland mapping exercise.

Ongoing advances in remote sensing that suggest that more detailed mapping will become more feasible due to: improvements in processing hardware and software, increased spatial and spectral resolution of sensors and reducing costs for data sets. The increased spectral resolution provided by sensors such as ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) may allow for more effective assessment of inundation of playa lakes. Aster also has 15m resolution for visible and NIR bands allowing for refined spatial application of algorithms such as NDWI. ASTER works on a 16 day cycle (similar to Landsat), but a combination of images from Landsat 5 and 7, plus ASTER will provide improved temporal resolution.

This inventory did not include detailed mapping of individual wetlands. Finlayson (1999), in his recommendations for protocols for an Australian inventory, proposes that this should be done at a scale of 1:50,000 or more detailed still:

- i Wetland regions with maps at a scale of 1:5 000 000
- ii Wetland aggregations with maps at a scale of 1:250 000
- iii Wetland sites with maps at a scale of 1:50,000 or 1:25,000' (Finlayson 1999, p.120).

For many wetlands it will be impossible to accurately map outer boundaries without considering local-scale landform, substrate and vegetation. This requires site visits and/or aerial photography at a scale of 1:50,000 or more detailed. However, for some wetlands the concept of an accurate boundary may not be meaningful. In the words of Pressey and Adam (1995, p.94): 'in view of the gradual and fluctuating nature of wetland edges, the establishment of precise but biologically meaningless boundaries might have limited use'.

An even more detailed scale would be necessary to map wetlands types, or zones, within some of the wetlands. However, for the large floodouts, it should be possible to delineate areas of persistent water (typically wooded swamps) from areas that are better classed as flood-prone flats, even at 1:250,000.

13.5 Creation of Generalised Digital Drainage Data

A need was identified for a simplified representation of existing mapping of major drainages.

Existing drainage mapping did not include an adequate dataset at a more general scale than 1:250,000. Existing 1: 1 million mapping was found to be too inaccurate for the purpose of analysing drainage systems and water supply and connection between wetlands. It was also inadequate for creating summary maps for inclusion in this report.

To address this need, various versions of generalised drainage were created from the 1:250,000 Geodata set (as obtained from AUSLIG now GeoScience Australia). For the arid NT, the Geodata consist of many (118,592) relatively small line sections (arcs). Attributing these arcs for stream order would be the most objective way of generating data for depicting only the major drainages. However, that large task was beyond our scope and a more subjective method was adopted. Also, defining stream order is problematic because channel size (depth and width) varies so much and often decreases due to floodouts, distributary channels and loss of flowing water into groundwater.

In the following explanation, a digital line section is referred to as an arc, while an actual drainage feature is referred to as a drainage line, channel, river or creek.

Data for Presentation at 1:500,000

Firstly, the existing 1:250,000 digital data of drainage channels were used to create a simplified dataset at the same resolution. This involved selecting a subset of existing drainage arcs and in some cases adding new connector arcs. The resulting dataset is deemed to equate to a mapping scale of about 1:500,000.

Only a subset of the existing arcs were already attributed with a creek or river name. These were used as an initial guide to the more substantial drainage systems. Tributaries or isolated drainage lines that were longer than 8km were included. Most of the shorter ones were not included, with a few exceptions. The process of establishing 'networks' of drainage did not include ensuring that all were topologically connected or oriented for flow direction.

Once the networks of the main drainage systems were established, they were pruned by dropping arcs from the dataset. The digital 1:1 million mapping was used as a guide in choosing which arcs to retain, as were satellite images and raster maps of the unpublished 1:100k topographic mapping.

Some spatial editing was undertaken to create a single arc for broad river sections and waterholes that are represented by parallel arcs or polygons in the 1:250,000 Geodata. Where rivers were mapped as consisting of multiple channels, the river was remapped as a single channel; either using existing 1:250,000 arcs or a new one digitised along the general path.

Arcs depicting flow along relatively linear floodouts or that connected channels and basins were also included in the dataset.

Data for Presentation at Smaller (less detailed) scales

The data were attributed to control which arcs are depicted in broader scale maps such as those in this report. An attribute field was set with values from 1 to 4, with 1 indicating upper tributaries through to 4 for the major drainage lines. This subjective process was driven by cartographic rather than hydrological considerations.

Two generalised data sets were created (values 3& 4, and 4 only), and the individual arcs were generalised with the ArcEdit 'bend simplify' option and a tolerance of 0.01 (degrees) corresponding to about 1 km.

Review and Mapping of Drainage Connectivity and Extent

Many drainage lines and networks are connected by surface water flow following large rain events, even though there are no connecting drainage channels shown on the 1:250k topographic maps. Various areas of unmapped surface flow connections were identified from anecdotal reports, field observations, observations from satellite images (Landsat TM) and floodouts mapped on the existing 1:250k topographic map sheets. Floodouts that are already mapped on the 1:250k maps are represented by various cartographic devices with significant differences between map sheets. Some are included in the digital data (Topo250K Geodata product) and some are not.

Method

A digital line coverage was created to represent all such surface connections. Surface flow connections were investigated using satellite imagery from as soon after major rain events as possible. The satellite imagery was all Landsat TM and included full ETM+ images that had been purchased and also some ACRES Quicklook images. The nature of the connections varied from relatively narrow linear flows to broad floodouts that were clearly not confined to a channel. For some areas, images from several dates after the rain event were examined, and in some cases an area of initial sheet flow was observed to recede to a residual linear surface water connection. However, it was generally not possible to infer the presence of an incised channel. The length of time between the rainfall event and the next useable image was quite varied due to clouds obscuring the relevant parts of some images and the interval between satellite passes. In some cases, the surface water connection was inferred, such as where a large sheet flow had nearly reached a mapped channel or waterbody. All connections were digitised as lines, however, the lines were attributed as to whether the surface flow was linear or broad. Where the observable surface water connection was not linear the new arc follows a somewhat arbitrary path across a floodplain.

Results

Linear connections were digitised for various drainages including: Karinga Creek, Coglin Creek, Snake Creek, the Lander River, Ingallan Creek, Dashwood Creek, 'The Derwent', Charlie Creek, Day Creek, Gidyca Creek, the interim Sandover River floodout at Ammaroo, and the lower Sandover floodout. The review of drainage connectivity was focused on major watercourses and was not comprehensive. Accordingly it is likely that some previously 'unmapped' connections were also not mapped by us.

For some rivers, flow was observed to continue for further than is shown on the existing 1:250k topographic mapping. New lines were digitised from satellite imagery to show extensions to the: Hanson River, Todd River, Hale River and Hay River. However, for the latter three, our extensions are considerably shorter than the channel lengths on the Oodnadatta 1:1 million scale topographic map.

Table 7 lists the images used to map connections and extensions which are shown in figure 11. The comments describing the nature of the areas are not comprehensive descriptions but provide some explanation of the nature of the connection or extension that was observed on the imagery.

Table 38. Satellite images used to map drainage connectivity and extension

Drainage: Basin / System (& location)	Image Information (QL= Quicklook) (TM= eTM+)	Comments
Mid to Lower Finke River System (Lake Eyre Drainage Division)		
Coglin Creek, Duffield Creek, Wall Creek Skull Creek & tributary (<i>S of New Crown HS</i>)	QL 101/78 16/2/00 TM 101/78 7/6/00	Various connections evident on 16/2/00 image and mapping of connections refined using 7/6/00 image. Continuity of Coglin Creek; linear flow (2 km). Continuity of Duffield Creek (4 & 3 km) to confluence with Coglin Creek; linear flow. Continuity of Skull Creek (9 km) & tributaries (3 km) to confluence with Coglin Creek; largely linear flow. Wall Creek (3 km) water filled connection to Coglin Creek evident on 16/2/00 image.
Karinga Creek (<i>SW of Idracowra HS</i>)	TM 102/77 26/3/00	Connection from termination of marked channels eastward (> 43 km) to Finke River, with continuous linear water channel evident on 26/3/00. Karinga Creek may have connected to Pulcura, Mygoora & Murphys Lakes during March 2000 but no cloud free imagery to support.
Snake Creek (<i>SSE of andado HS</i>)	TM 101/78 7/6/00	Water filled linear flows cross-cutting dunes and filling interdune swales (total 43 km) evident in 7/6/00 image along distributary channel of the Finke River, known locally as 'Snake Creek'.
Sandover River System (Lake Eyre Drainage Division)		
Ooratippra Creek to Sandover River	QL 101/75 3/3/00 TM 101/75 6/5/00 QL 101/75 1/1/01	Floodout, with broad linear flows, 45km connection to Sandover River evident in images 3/3/00 & 1/1/01. Mapping refined using 6/5/00 image.
Sandover River to Georgina (<i>Ammaroo, Ooratippra, Argadargada & Lake Nash Stations</i>)	QL 101/75 3/3/00 TM 101/75 6/5/00 QL 101/75 1/1/01 TM 100/75 31/5/00 QL 100/75 10/1/01	Five zones of drainage extension defined, showing continuity of Sandover River through to Stokes/Bybby Creek (mapped tributary of Georgina R.). Mapping based on two separate flow events: March-May 2000 and January 2001. Sandover floodwaters may not have reached the Georgina in 2000 but certainly did in 2001. The Amaroo Sandover floodout was inundated in 2000 but not in 2001. As well as connecting across the floodout between previously mapped channels, Sandover floodwater probably connected to the Bundey River directly across the floodout. Ammaroo floodout water connection over 8.5km zone. Largely broad floodout with connection evident on 3/3/00 image and refined using 6/5/00 image. Ooratippra-Argadargada 33.5km extension of existing Sandover River AUSLIG drainage based on water filled anastomosing flow zones on image 6/5/00, supported by 3/3/00 image. Argadargada 39.1km extension based on anastomosing flow floodout from image 1/1/01, refined using 6/5/00 image. Argadargada-Georgina Downs, connection of Sandover River to Stokes Creek (56.9 km) by water filled braided to linear flow from 1/1/01 and 10/1/01 images, refined from 31/5/00 image. Sandover floodwater probably also connected to the Milne River via Argadargada Waterhole (floodwaters were 1km from the mapped channel of Milne R on 10 Jan 2000; connection not digitised). Substantial amounts of water also flowed northeast, to the north of the mapped connection to Stokes Creek. Some inundated the feature mapped as 'Ancient Watercourse' (10 Jan 2001 – cloud obscuring substantial areas). Connection between Stokes and Bybby Creeks (7 km), partially 'constrained' linear flow, evident in 10/1/01 image.
Other Georgina Basin Drainages (Lake Eyre Drainage Division)		
Imborditure & Thingua Creeks (<i>WNW of Tobermorey HS</i>)	TM 100/75 6/5/00 QL 100/75 10/1/01	Both dates used to define extensions to tributaries (6 & 47 km), including Thingua Creek extension (6 km), and connection between AUSLIG mapped Imborditure Creek channels (11 & 16 km). Broad linear features but no cloud free images available for subsequent dates with which to map presumed narrower linear water flow.
Barkly Basin (Western Plateau Drainage Division)		

Elkedra River	TM 101/75 6/5/00 QL 101/75 1/1/01 QL 101/75 2/2/01	Drainage link of 14 km, with contained linear flow, interpreted from 1/1/01 images & 6/5/00. Terminal floodout mapped as 27km extension, with local contained linear flow, from 2/2/01 image, refined from 6/5/00 image.
Burt Basin Drainages (Western Plateau Drainage Division)		
Charlie Creek Amburla Creek The Derwent Dashwood Creek Day Creek Gidyca Creek (Lake Lewis area)	QL 3/76 1/3/00 TM 103/76 2/4/00	The connection of five tributaries to Lake Lewis was mapped using images following heavy rains in February 2000. Connections were inferred but not conclusively shown. Floodout connection of six creeks to Lake Lewis can be inferred from the 1/3/00 image: Amburla Creek (49 km) plus an unnamed creek (56 km); Dashwood Creek (25 km); Day Creek (27 km), Gidyca Creek (34 km); & The Derwent (40 km). Floodouts vary from anastomosing broad flow zones to linear flows as is evident in 2/4/00 image.
Wiso Basin (Western Plateau Drainage Division)		
Bonney Creek	QL 103/74 17/3/00 TM 103/74 29/1/00 QL 103/74 5/4/01	Bonney Creek has 37km extended braided floodout passing into linear flow zone mapped from 17/3/00 & 29/1/00 images. Surface water is apparent to the south of Porcupine Swamp. Bonney Creek is mapped as extending through and to the north of the swamp without the swamp filling.
Hanson River	QL 103/74 17/3/00 TM 103/74 29/1/00	The Hanson River has 42km extended anastomosing flow zone to single linear floodout mapped from 17/3/00 & 29/1/00 images. An arc has been added that shows the central flow through the area marked on the 1:250K topo map as a floodout (not in the digital waterbodies dataset) and extend about 15km further north of the mapped floodout.
Ingallan Creek	QL 103/75 1/3/01	Four sections (total of 20 km) identified connecting Ingallan Creek into the Lander River, across a floodout.
Lander River	QL 104/74 27/3/01	Three connecting sections (total 42km) to SE of Lake Surprise are water-filled in 27/3/01 image.
McLaren Creek	QL 103/74 17/3/00 TM 103/74 29/1/00	McLaren Creek has 26km of extended braided floodout passing into a linear flow zone mapped from 17/3/00 & 29/1/00 images. On the quicklook TM image of 5/4/01 waters of both McLaren and Gilbert Creeks appear to be almost connecting to Bonney Creek.
Skinner Creek	TM 102/75 26/3/00 QL 102/75 13/3/01	Braided-flow zone passing to single linear flow extension Skinner Creek (29 km) evident in 13/3/01 image, refined from 26/3/00 image. Mapped as extending to within 2.5km of Thring Swamp (on the Wycliffe Creek floodplain).
Taylor Creek	TM 102/75 26/3/00 QL 102/75 13/3/01	Broad floodout extension of Taylor Creek (30 km) evident in 13/3/01 image, refined to more linear flow zones using 26/3/00 image. Mapped as extending to within 12km of the Wycliffe Creek floodout.
Woodforde River	QL 103/75 1/3/00	Connection Woodforde River over 35km to Hanson River evident on 1/3/00 image, with continuous water-filled linear flow zones and some broader floodout zones. The Woodforde runs parallel to the Hanson for several km before the confluence.
Wycliffe Creek	QL 103/74 17/3/00 TM 103/74 29/1/00	Wycliffe Creek has 29km of extended sheet and braided floodout reforming into a linear flow zone mapped from 17/3/00 & 29/1/00 images.
Yaloo garrie, Atlee & unnamed Creeks (NW of Yuendumu)	QL 104/75 27/3/01 TM 104/75 12/6/00	Extensive sheet and braided floodout with some linear flow zones evident in 27/3/02 image. Refined mapping using 12/6/00 image. Extension/connections: Yaloo garrie Creek - 19 km; Atlee Creek - 30 km; and unnamed - 22km.

Note: some of the images were from dry times where a full TM image was available and allowed better interpretation of landscape features.

Delineating Floodout Areas with Remote Sensing

In addition to mapping the connectivity of drainage across floodouts, there is a need to map their extent.

River floodout wetlands are depicted in various ways on the 1:250,000 scale topographic maps. Consequently only some floodouts are included in the associate digital data (Geodata waterbodies coverage). In addition, the areas mapped as floodout often have a poor correspondence to areas of persistent inundation in swamps and lakes. We used Landsat 7 ETM+ multi-spectral data to determine where the persistent inundation was in two examples: the floodouts of the Frew and Elkedra rivers. Images and maps illustrating these issues are presented in Appendix 2. The extent of floodout mapped on topographic maps may well correspond reasonably to the extent of flooding. However, some of these areas do not hold surface water for long and would be best classified as flood prone flats under our classification. A detailed review of Landsat data from dates of extreme inundation is required to refine the mapping of floodouts.

13.6 Remotely Sensing of Inundation Patterns

The vast majority of wetlands in the arid NT are only inundated temporarily. The inundation regime is an important ecological driver of these wetlands; incorporating the parameters of frequency, seasonality, depth and duration. However, defining and documenting such regimes is not easy. Typically there is little information available.

The substantial archives of satellite imagery for Australia provide an opportunity for investigation of inundation regimes with remote sensing. A recent study (Roshier *et al.* 2001) has pioneered the remote sensing of arid zone inundation regimes at a continental scale. That study used NOAA AHVRR satellite data, with a cell size of roughly 1.1 by 1.1km and modeled the relationship of rainfall to inundation detected on the imagery.

In this section we assess the results of that work for the arid NT. We also discuss the applicability of the methods of extrapolating patterns from remotely sensed data using rainfall records. As part of this we undertook a case study of inundation patterns in Lake Bennett; a salt lake on Newhaven Station. Some series of inundation patterns were investigated using satellite imagery for some other wetlands for the study area and notes on these are included in Volume 2.

Review of Methods and Results in the Study by Roshier *et al.* (2001)

The model developed by Roshier *et al.* (2001) involved:

- (1) An assessment of the spatial distribution and temporal variation in the area of wetlands in arid and semi-arid Australia (5.4Mkm²) using NOAA AHVRR satellite data over the period September 1986 to September 1997.
- (2) Subdividing the study area into seven regions based on National Drainage Basins and prevailing weather patterns.
- (3) Relating documented wetland-filling events to particular weather systems or climatic phenomena in addition to interpolated recorded rainfall data.
- (4) Developing linear regression models of changes in wetland areas related to rainfall and spatially variable weather systems and climatic phenomena.
- (5) Utilising historical rainfall records over the period 1889 to 1995 together with modelled thresholds to hindcast wetland filling events.

Our study area of the arid NT wetlands lies within the Northern Deserts (eastern margin) and Upper Eyre (SW margin) regions defined by Roshier *et al.* (2001). The relevant conclusions from their study are summarised as follows and critically reviewed below. It is important to note that there is a large latitudinal gradient in climate and rainfall in particular in both the 'Northern Deserts' and 'Upper Eyre' regions and that the summary of inundation patterns by Roshier *et al.* (2001) is at a correspondingly coarse geographic scale. Also, the area defined as the Northern Deserts extends well north of the arid NT study area, incorporating areas of higher annual rainfall and much stronger seasonality and predictability of rainfall.

For the Northern Deserts region, Roshier *et al.* (2001) describe regular annual occurrences of wetland filling events the longest period between events being 2 years. During the 11 year period of the inundated area assessment, a peak area of 80km² of inundated areas was documented for a six month period in 1993. Four other six month periods of inundated areas exceeding 18km² were identified and inundated areas of <10km² were defined for the remainder of this period.

For the Upper Eyre region, Roshier *et al.* (2001) describe annual occurrences of wetland filling events as commonly occurring within this region, the longest period between events being four years in the late 1920s. During the 11 year period of the inundated areas assessment, two peak areas of >150km² of inundation were documented for six month periods in 1991 and 1997, with four other periods of inundated areas exceeding 20km² and inundated areas <10km² for the remainder of this period.

Limitations of their analysis noted by Roshier *et al.* (2001) include:

- a. the distribution of rainfall recording stations is variable and in some cases sparse, creating uncertainty in the magnitude of interpolation errors;
- b. a longer period of data to establish the rainfall/wetlands filling relationship is desirable;
- c. correction of the rainfall/wetland filling relationship for evaporation would improve the model;
- d. cloud cover provided some constraints on assessment of wetland area during some periods; and
- e. the limited spatial resolution of the AVHRR multi-spectral imagery.

We note some additional limitations at the finer scale of the arid NT study area. The method of Roshier *et al.* (2001), applied at a continental scale, does not account for substantial variation that exists in the duration of inundation events and the proportion of individual waterbodies that are inundated in a particular event. These factors can be very important influences on the biota. Roshier *et al.* (2001) use regional rainfall over three and six month periods in the regression models they developed to 'hindcast' inundation events. In interpreting the associated results, it is important to understand the variation in rainfall intensity that occurs and the influence of intensity on the amount of runoff and stream flow that occurs. Rainfall records at most recording stations are limited to daily figures. However, daily figures provide quite limited information about intensity. Hourly rainfall data is a much stronger indicator of runoff amounts and therefore also to areas and depths of resulting wetland inundation. Moderately high daily, weekly and monthly rainfall figures cannot be assumed to have generated high levels of runoff.

Further consideration of some of the terminology adopted by Roshier *et al.* (2001) is useful in exploring the applicability of their results. They use two phrases to describe the nature of inundation: 'wetland filling events' and 'periods when increases in wetland area have occurred'. Wetland filling events are defined as positive changes (i.e. increases) in wetland area. However, this definition dramatically simplifies the range and variation of inundation events that actually occur. Also, the term 'filling' is difficult to apply consistently when interpreting remote sensing information only. Most of the large wetlands in arid Australia are relatively flat, with a moderate gradient at their margin. Extensive very shallow inundation may occur across much of the wetland, but these shallow inundation events are not generally perceived as 'filling of the wetland'. Major inundation events that are deeper and are genuine 'filling' events may not be easily distinguished from minor events using remote sensing unless images from multiple dates are inspected to determine the longevity of surface water in individual wetlands.

Graphical presentation by Roshier *et al.* (2001) of the area of inundation for the various regions provides some insight to understanding the nature of inundation referred to and their meaning in the phrase 'periods of increasing inundation area'. For example, while regular annual 'filling' events are concluded to occur in the Northern Deserts Region, relatively large and long lasting areas of wetlands are not annual events. The graphical data provided for periods of increasing inundation area ('filling' events) suggests that inundation areas totaling >10km² in this region are likely to occur for only 30 - 50% of the 105 years assessed. Similarly, while annual 'filling' events are referred to as common in the Upper Eyre region, large areas of inundation are not common events. The graphical data provided for periods of increasing inundation area ('filling' events) suggests that persistent inundation areas totaling >10km² in this region are likely to occur for only 20 - 40% of the 105 years assessed.

Lake Bennett Case Study

We examined the inundation history of Lake Bennett (22° 50' S, 131° 02' E, area 9,540km²) over a 22 year period (July 1979 to June 2001). Lake Bennett was selected as an example of the larger playa lake systems in arid NT, with an important consideration being the proximal rainfall recording at Newhaven Homestead over the period of available satellite imagery. We assessed the magnitude of inundation by visual estimation of area of surface water inundation from Landsat MSS, TM and ETM+ 'quicklook' images available from the ACRE's Digital Catalogue. Three classes of inundation event were defined:

- 1) major inundation - greater than 30% of lake area for greater than 3 months;
- 2) minor inundation - greater than 20% of lake area for greater than 1 month; and
- 3) very minor inundation - greater than 20% of lake area for less than 1 month.

An example of an interpreted minor inundation event is provided in figure 21.

The spectral limitations of the imagery used are discussed below, but it is considered that this semi-quantitative approach allows for a reasonable assessment to be conducted. The most significant limitations to this case study were periods of persistent cloud cover and minor gaps in the availability of imagery. To take into account the potential for Lake Bennett to receive a significant groundwater contribution to its water budget a three monthly moving average of rainfall is included together with the recorded rainfall at Newhaven Station.

The documented inundation events at Lake Bennett over the 22 year period examined are summarised as:

- (1) at least one very minor inundation event (>20% inundation, <1 months persistence) occurs annually;
- (2) more significant minor (>20%, >1 month) and major (>30%, >3 months) inundation events are not annual events but occur in >80% of the years during the period examined;
- (3) major inundation events occur in 5 of the 22 years examined, but are not evenly distributed temporally, occurring in clusters; and
- (4) in the case of Lake Bennett the application of a threshold of a total of 60mm rainfall over three succeeding months will in most cases result in an inundation event.

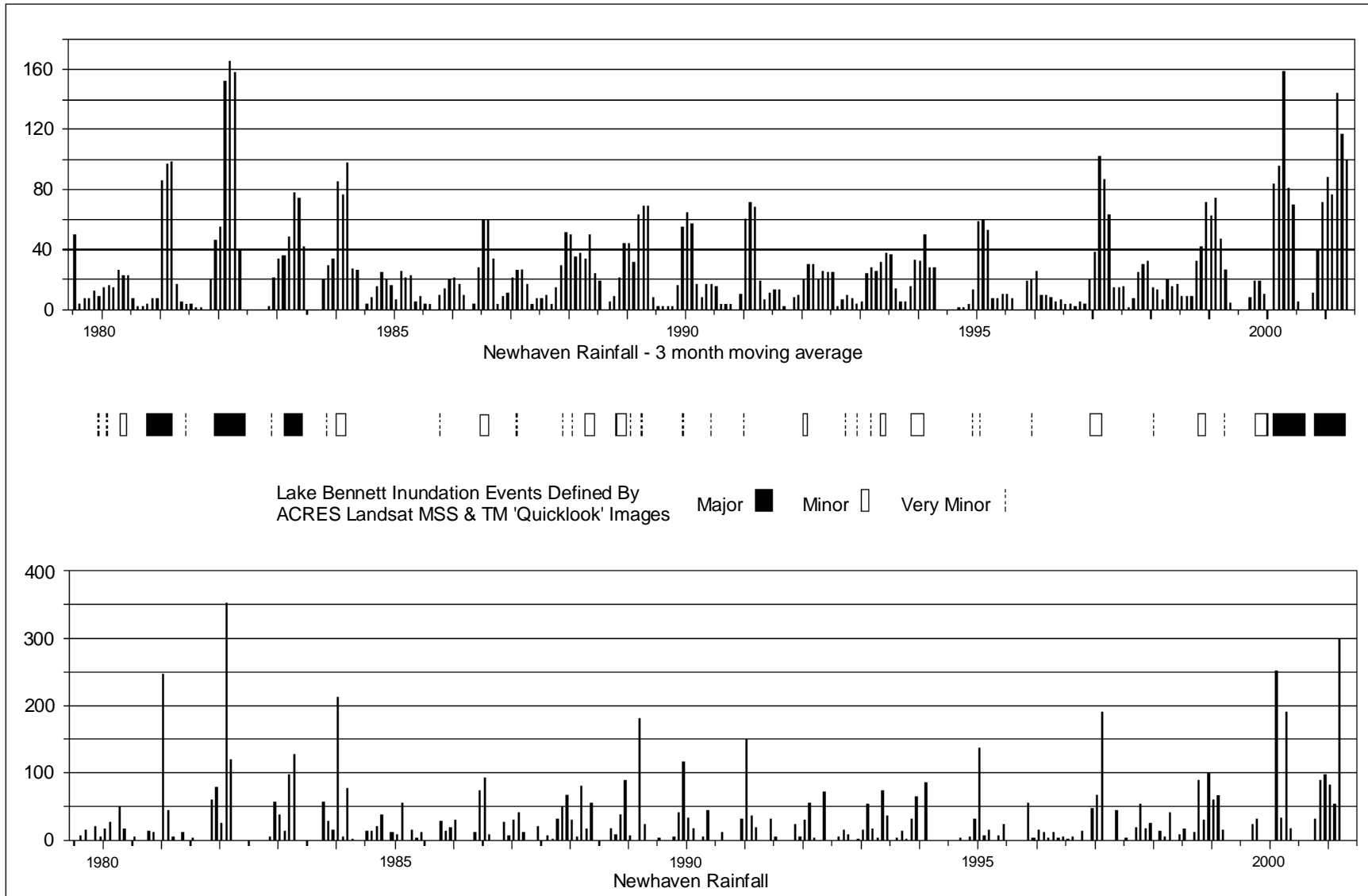


Figure 21. Lake Bennett rainfall and inundation diagram.

Conclusions

In this context the broad conclusions of Roshier *et al.* (2001) can be more confidently and quantitatively interpreted in their application to arid NT. The stated regular to common annual wetland 'filling' events in the Northern Desert and Upper Eyre regions correspond with some wetland inundation. However, the scale and persistence of these inundations is highly variable and aseasonal. The most common events produce waterbodies that persist for less than 1 month and occupy only a small proportion of the capacity of mapped wetlands. Inundation events producing waterbodies constituting >20% of waterbody surface area, that persist for greater than one month, can be considered to be common. Major wetland filling events, producing waterbodies of greater than 3 months persistence and filling a significant proportion of waterbody surface area (>30%) tend to occur in clusters and their frequency can be measured in decades rather than annual occurrences.

A quantitative and refined assessment of the inundation patterns for the whole of the area of arid NT wetlands is feasible, although it would be time consuming and expensive. Refinement of the modeling and data sets used by Roshier *et al.* (2001) specifically for this region would produce more refined and detailed conclusions. Additional spatial and spectral resolution could be achieved using the archive of Landsat MSS, TM and ETM+ available for the period 1972 to present. However, attempting to quantitatively analyze even a portion of the Landsat archive would be a mammoth task, requiring radiometric calibration, registration and rectification for a huge volume of multi-spectral data. It is questionable if such an approach would be justified in the context of the important limitations highlighted by Roshier *et al.* (2001), namely the sparse and uneven distribution of rainfall recording stations, especially in the arid NT. The regional rainfall modeling and interpretation of weather systems that was applied by Roshier *et al.* (2001) is clearly superior to gridding of sparse rainfall data points. However, the arid NT has extreme rainfall variability and is located near the southern margin of influence of the tropical weather systems that are interpreted to most strongly influence inundation events in the Northern Desert and Upper Eyre regions.



14. Conservation Significance of Wetlands

Scope

This section analyses the concept of biological significance at various geographic levels (regional to global). The concept of 'important wetlands' is also discussed along with the criteria for national and international importance. Those wetlands in the arid NT that have been identified as important are listed.

14.1 Framework for Assessing Significance and Importance

A Directory of Important Wetlands in Australia (hereafter referred to as the Directory) sets out criteria for inclusion of wetlands. Likewise, there are criteria for the Ramsar list of internationally important wetlands. Both the Directory and the Ramsar list have a biodiversity conservation focus. However, both sets of criteria allow wetlands to be included because they are good examples of a wetland type in a biogeographical region. This allows wetlands to be listed even in the absence of detailed data on flora and fauna values. Where such data exist, a more objective assessment of conservation significance is possible. The Directory also includes a criterion of 'outstanding historical or cultural significance'. In this report we make a distinction between conservation significance and the more general concept of wetland 'importance'.

We have identified wetlands that meet the criteria for inclusion in the Directory. We have further rated them for conservation significance at three geographic scales: regional, national and international. Our rating system is informal and somewhat subjective but provides a useful way of discriminating those wetlands with greater known biodiversity values from those with fewer known values. Regional significance is equated here with significance for maintaining biodiversity in the study area or within a particular bioregion. In making our assessments we considered the value of a wetland or wetland aggregate for the conservation of both species and communities of flora and fauna,

Most of these assessments must be regarded as preliminary due to the general paucity of data including data on:

- existence of individual wetlands;
- the general ecological character of individual wetlands;
- specific flora and fauna values of individual wetlands;
- general ecology and population parameters of many individual species.

In the arid NT all permanent and very long-term wetlands are considered important because of the aridity of the general landscape. However, the longevity of many individual waterholes is not yet recorded, including those in areas where permanent waterbodies are known or thought to occur such as the MacDonnell, Davenport, Murchison and Dulcie Ranges. We were not able to individually describe all the permanent waterholes for potential inclusion in the Directory. Some information about individual permanent waterholes is collated in volume 2 of this report.

Some of the wetlands that are not presently identified as nationally important may have unknown values which make them individually important, and others may collectively be very important. Whitehead and Chatto (1996) discuss the importance of collections of wetlands. Regional collections of wetlands provide the habitat necessary for sustaining regional populations of species. Even though individual wetlands may only support small populations of widespread species they are still important. Degradation

of many of the component wetlands could have serious consequences for the species they support. Gibbs (2000) states that reductions in wetland density can adversely affect total populations of organisms that depend on wetlands. Examples of arid NT wetland types to which this may apply are some of the smaller swamps and claypans. It is important not to overlook the importance of such collections of wetlands even though they do not meet the criteria for the Directory or the Ramsar list.

Some of the wetlands that we have identified as potential Directory sites are composed of several distinct individual wetlands. These wetland aggregations are used to present information about wetland areas for which there is insufficient information to assess or describe individual wetlands and for which the whole aggregation has notable importance for biodiversity.

14.2 Criteria for Including a Wetland in A Directory of Important Wetlands in Australia

According to the third edition of *A Directory of Important Wetlands in Australia* (Environment Australia 2001), a wetland may be considered nationally important if it meets at least one of the following criteria:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles, or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports 1% or more of the national populations of any native plant or animal taxa.
5. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
6. The wetland is of outstanding historical or cultural significance.

14.3 Application of the Ramsar Criteria in the Arid NT

The criteria for assessing the international importance of individual wetlands are defined under the international agreement known as the Ramsar Convention and are listed in full in appendix 7. Here we discuss the application of some of the criteria to arid NT wetlands. Assessments of the international importance of some arid NT wetlands are included in volume 2.

The Ramsar Key Document *Strategic framework and guidelines for the future development of the List* (internet site of Ramsar: [key_guide_list_e.htm](#)) provides additional information on goals for the Ramsar List and criteria for the inclusion of sites. Some of these guidelines are listed and discussed below.

Goals for the Ramsar List

Item 67 of the Key Document gives a long-term target of including at least one suitable representative of each Ramsar wetland type from each bioregion. The IBRA bioregions (Interim Biogeographic Regionalisation of Australia, Thackway & Cresswell 1995) meet the Ramsar guidelines for regionalisation yet may be considered to be at a relatively fine resolution. Thus, the goal of listing a representative example of each wetland type in each bioregion might be appropriately interpreted as applicable to a larger area than individual IBRA bioregions. For example, a rockhole in the Great Sandy Desert bioregion may have unique attributes for that bioregion but be unremarkable in the context of the nearby MacDonnell Ranges bioregion. Because all the arid NT bioregions consist of single simple polygons it is common for areas typical of one bioregion to occur as outliers in another. There are currently no guidelines for dealing with this issue in assessing sites for conservation importance at both

the national and international (Ramsar) level. However, guidelines for applying the Ramsar criteria in Australia are in preparation (R.Jaensch pers. comm.).

Item 68 encourages Contracting Parties (countries) to determine the range of wetland types, using the Ramsar classification, in each bioregion and identify those sites which provide the best examples of each. Whitehead and Chatto (1996) warn against focusing only on identifying 'best sites' for *A Directory of Important Wetlands in Australia* as often biota depend on a range of wetlands across the landscape. This point is also given some recognition in the Ramsar guidelines in item 74,

'greatest conservation value will be achieved through selection of a network of sites' (internet site of Ramsar: key_guide_list_e.htm),

however, this point is easily overlooked in the wealth of Ramsar information and the warning of Whitehead and Chatto is an important reminder that isolated 'best sites' generally have limited conservation value on their own.

Furthermore, within each type, there is an enormous variation in attributes such as inundation regime, dominant vegetation and wetland size. Although classification helps in summarising and describing the wetlands of the area there is a great deal of diversity within each type. Therefore, attempting to identify the best example of each type is not always meaningful. The concept of a 'good example' as used in the Directory is more appropriate.

Item 74 concerns criterion 2 concerning threatened species and communities. The guidelines for this have an apparent emphasis on birds but also includes a priority on including sites which

'hold a high proportion of the population of a dispersed sedentary species that occupies a restricted habitat type' (internet site of Ramsar: key_guide_list_e.htm),

This applies well to plants.

Item 75 concerns ecological communities about which there is little hard data for the arid NT.

Item 78 gives the following priority characteristics for selecting Ramsar sites:

- i. Are 'hotspots' of biological diversity and are evidently species-rich even though the number of species present may not be accurately known; and/or
- ii. Are centres of endemism or otherwise contain significant numbers of endemic species; and/or
- iii. Contain the range of biological diversity (including habitat types) occurring in a region; and/or
- iv. Contain a significant proportion of species adapted to special environmental conditions (such as temporary wetlands in semi-arid or arid areas); and/or
- v. Support particular elements of biological diversity that are rare or particularly characteristic of the biogeographic region.' (internet site of Ramsar: key_guide_list_e.htm)

Clearly point iv concerning species adapted to arid areas is relevant to a great many arid NT wetlands.

Ramsar List 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.

Criterion 4 is very broad and could include a vast number of wetlands which support plants and animal species at a critical stage in their life cycles. It is hard to know how to apply this criterion objectively and usefully in the arid NT. The guidelines for criterion 4 (see items 80 and 81 are below) also make special mention of the arid zone; potentially widening their applicability in the arid NT.

'80. Critical sites for mobile or migratory species are those which contain particularly high proportions of populations gathered in relatively small areas at particular stages of life cycles. This may be at particular times of the year or, in semi-arid or arid areas, during years with a particular rainfall pattern. For example, many waterbirds use relatively small areas as key staging points (to eat and rest) on their long-distance migrations between breeding and non-breeding areas. For Anatidae species, moulting sites are also critical. Sites in semi-arid or arid areas may hold very important concentrations of waterbirds and other mobile wetland species and be crucial to the survival of populations, yet may vary greatly in apparent importance from year-to-year as a consequence of considerable variability in rainfall patterns.

81. Non-migratory wetland species are unable to move away when climatic or other conditions become unfavourable and only some sites may feature the special ecological characteristics to sustain species' populations in the medium or long-term. Thus in dry periods, some crocodile and fish species retreat to deeper areas or pools within wetland complexes, as the extent of suitable aquatic habitat diminishes. These restricted areas are critical for the survival of animals at that site until rains come and increase the extent of wetland habitat once more. Sites (often with complex ecological, geomorphological and physical structures) which perform such functions for non-migratory species are especially important for the persistence of populations and should be considered as priority candidates for listing.' (internet site of Ramsar: key_guide_list_e.htm)

Ramsar List Criterion 5

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

Criterion 5 arguably does not apply in the arid NT since there is no such site. The only wetlands supporting such large populations do so episodically and may qualify as Ramsar sites under the guidelines for criterion 4 as presented above. The term 'regularly' is discussed in Appendix B of the key document *Glossary of terms used in the Strategic Framework*. Some flexibility is suggested for arid zone sites although a general definition of 'two thirds of the seasons' is given. If a long-term view is taken it is arguable that the episodic inundation events in arid NT salt lakes are regular, being likely to occur several times a century.

Ramsar List Criterion 6

A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

The application of criterion 6 also hinges on interpretation of the term 'regular'. 'Population' as used in criterion 6, is loosely defined in the glossary, as the relevant biogeographic population. In 2001 Lake Mackay probably had well over 1% of the global population of Banded Stilts.

Ramsar List 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.

Several items of the guidelines aid in interpretation of criterion 7 concerning fishes. Item 92 concerns the international importance of sites with a high diversity of fishes. Three isolated arid NT drainage networks have a high diversity of fishes relative to much of the arid zone. The Finke River system has 9 species; the Whistleduck Creek system has seven and the Frew River system has six. The Sandover River system has 5 recorded species but the significance of this diversity is reduced due to the occasional connection to the Georgina River system (c. 11 species) and the possibility that some species do not persist in the Sandover and are only present following colonisation from the Sandover. None of these numbers is high in global terms but are moderately high in terms of the Australian arid zone. Wager and Unmack (2000) give numbers of species by national drainage basin for the greater Lake Eyre basin, of which The Cooper Creek basin has 19 indigenous species and the Georgina and Diamantina basins both have 11.

The guidelines on assessing significance of fishes direct that diversity alone is an inadequate measure and that other ecological factors should be assessed including interactions between species, with the environment and endemism. Item 94 gives a threshold value of 10% endemism. Only the Finke system (33% endemic) satisfies it and one of the species is listed as threatened and another is considered rare; further adding to the case for international significance of the permanent waterbodies in the upper Finke River system. The long isolation of the Frew and Whistleduck drainages may be grounds for claiming international significance of their fishes but they do not clearly qualify.

Ramsar List 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.

Criterion 8 is designed to identify the importance for areas of fish habitat that are important at particular times such as breeding or as a source of food. Since all arid NT fish populations rely on permanent and semi-permanent pools within the river systems, this criterion has little applicability. In the arid NT some fishes may breed in biologically productive swamps in lower parts of the catchments but these are generally isolated from the refuge pools and typically dry out (with the resulting death of any fishes in them) before they are reconnected to the refuge pools.

14.4 Important Wetlands in the Arid NT

Existing and Potential Directory Wetlands

Prior to this inventory there were four arid NT wetlands listed in a *Directory of Important Wetlands in Australia* (hereafter referred to as the Directory or DIWA): 'Lake Surprise (Yinapaka)', 'Lake Amadeus', the 'Karinga Creek Paleodrainage System' and the 'Finke River Headwater Gorges System'. Of these, the last two are aggregations of individual wetlands.

We have identified a further 46 wetlands that would contribute well to the directory. Half (23) of these are aggregations of multiple individual wetlands. Therefore, the number of new potential Directory sites is less than the number of individual significant wetlands. We have also suggested removing one of the existing DIWA wetlands in favour of two new ones: 'Finke River Headwater Gorges System', replaced by 'Chewings Range Permanent Springs' and 'Permanent and Long-term Waterholes of the Finke River System'.

Description and Nomination of Wetlands for Inclusion in the Directory

For 10 of the 46 potential new DIWA wetlands, we have prepared a full descriptive account in the form required by DIWA, and stored it in a DIWA compatible database. These descriptive accounts are presented in Volume 2 of this report. For the others we have prepared only summary descriptions; stored in the same database. The summary descriptions are presented by bioregion in the next chapter of this volume.

It is important that the concerns of landholders be respected in building partnerships for the conservation of biodiversity values. Many landholders in the study area are very concerned about unauthorized visitation to sites on their properties and this makes some landholders wary of sites being listed in the Directory.

None of the wetlands that we have identified as important for conserving biodiversity have been nominated for inclusion in *A Directory of Important Wetlands in Australia*. It is proposed that landholders need to approve of and be part of any such nominations. The managers and/or owners of pastoral leases with identified potential Directory sites have all been informed in writing and the Central Land Council has been advised regarding sites on Aboriginal Land Trusts. A process of considering nominating wetlands on reserves managed by Parks and Wildlife has been commenced.

The Parks and Wildlife Service of the Northern Territory does not endorse listing of any wetlands in material for public circulation without landholder approval.

Conservation Significance Levels of Potential Directory Wetlands

Each of the 46 potential new Directory wetlands was assessed against the DIWA criteria using available data. The most likely potential Ramsar wetlands were also assessed against the Ramsar criteria. The amount of data on flora and fauna values varied greatly between sites so this assessment is far from comprehensive.

As stated above, we also rated each of these wetlands (or wetland aggregate) for conservation significance at a regional, national and international level.

The wetlands identified as potential Directory sites are listed in table 39 and their locations shown in figure 22.

Table 39. Potential wetlands for inclusion in the Directory and their significance rating.

Wetland_name	Aggregation	Bioreg.	DIWA criteria	Ramsar criteria	DIWA account preparation status
National/International (11)					
Alice Springs Sewage Ponds		MAC	3		minimal
Chewings Range Permanent Springs	Y	MAC	1, 3	1, 3	complete draft
Dulcie Ranges Springs and Waterholes	Y	BRT	1, 3	?1, ?3, ?4	complete draft
George Gill Range Springs and Rockholes	Y	MAC	1, 3	1, 3	complete draft
Lake Lewis		GSD	1, 3	?1, ?5	complete draft
Lake Mackay	Y	GSD	1 4, ?5	1, ?2, ?4, ?5, ?6	complete draft
Palm Valley Area Springs, Rockholes and Palm Groves	Y	MAC	1, 3, 4, 5	1, 2, 3, ?4	complete draft
Permanent and Long-term Waterholes of the Finke River System (replacing Finke River Headwater Gorges)	Y	MAC	1, 2, 3, 4, 5	1,2,3,4,7	complete draft
Permanent Waterholes of the Davenport Ranges National Park	Y	DAV	1, 2, 3, (possibly 4)	?1, 2, 3, ?3	complete draft
Snake Creek Interdune Floodout Lakes	Y	SSD	1, ?3	1, 3, ?5	complete draft
Talipata Spring		MAC	1, 3	3	complete draft
National (8)					
Casuarina Swamp		SSD	1, 4, 5	not assessed	minimal
Elkedra River Floodout Swamps	Y	TAN	1, 2, ?3	not assessed	minimal
Finke Floodout Forest		STP	1	1	minimal
Karinga Creek Paleodrainage System (lakes of)	Y	FIN	1,4,6	not assessed	in DIWA
Lake Surprise (Yinapaka)		TAN	1,2,3	not assessed	in DIWA
Lander River Floodout Swamps and Waterholes	Y	TAN	1, 4, 5	2	minimal
Newhaven Lakes	Y	GSD	1	?1	minimal
Stirling Swamp	Y	BRT	1, 2, 3, 4, 5	2	minimal
National/Regional (5)					
Frew River Floodout Swamps	Y	DAV	1, 2, ?3	not assessed	minimal
Illparpa Valley Wetlands	Y	MAC	1, 3, 4, 5	not assessed	minimal
Lake Amadeus		GSD	1	not assessed	in DIWA
Mudhut Swamp		BRT	1	not assessed	minimal
Woodduck Swamp		BRT	1	not assessed	minimal
Regional (24)					
Ancient Swamp		TAN	1	not assessed	minimal
Blue Bush Swamp (Burrumurra)		MGD	1	not assessed	minimal
Duffield Swamp		STP	1	not assessed	minimal
Ettenia Spring		FIN	1	not assessed	minimal
Field River Floodout and other swamps	Y	SSD	1?	not assessed	minimal
Indemina Swamp		SSD	1	not assessed	minimal
Indinda Swamp		SSD	1	not assessed	minimal
Kangaroo Dam Swamp		FIN	1	not assessed	minimal
Lake MacDonald		GSD	1	not assessed	minimal
Lake Neale		GSD	1	not assessed	minimal
Large Semi-permanent Waterholes of the Georgina River System (NT portion)	Y	MGD	1, 3	not assessed	minimal
Narwietooma Lignum Swamp		BRT	1	not assessed	minimal
Northern Simpson Desert Area Lakes	Y	SSD	1	not assessed	minimal

Ormiston - Glen Helen Mound Springs	Y	MAC	1	not assessed	minimal
Pine Hill and Conniston Springs	Y	BRT	1	not assessed	minimal
Rainbow Valley Claypans	Y	MAC	1	not assessed	minimal
Ringwood Bluebush Swamp		MAC	1	not assessed	minimal
Salt Creek Lake		FIN	1	not assessed	minimal
Sanctuary Swamp		TAN	1	not assessed	minimal
Sandover Highway Wooded Swamp		MGD	1	not assessed	minimal
Skull Creek Swamps (New Crown)	Y	STP	1	not assessed	minimal
Small Spring-fed Waterholes of the Toko Ranges	Y	CHC	1, 2, 3	not assessed	minimal
Wycliffe Creek Floodouts	Y	TAN	1	not assessed	minimal
Yellow Hole Bore Swamp		MGD	1	not assessed	minimal
Suspected Regional					
Warrabri Swamp - Skinner Creek Floodout		TAN	1	not assessed	minimal
Superseded (presently in DIWA)					
Superseded site: Finke River Headwater Gorges System	Y	MAC		not assessed	in DIWA

Discussion of Significance Ratings of the Potential New Directory Sites

National / International

Due to the subjective nature of the criteria and the political aspect of the Ramsar listing process, sites of potential international significance have been rated as 'national/international significance'. There were 11 such wetlands or wetland aggregates that were identified at this level. The Alice Springs Sewerage Ponds were included for their importance for wetland birds, including as a migratory rest point.

National

The 8 wetlands rated as being of 'national significance' had known or suspected values for threatened species or supported a diverse suite or abundance of wetland organisms, but less clearly met Ramsar criteria.

National / Regional

There were 5 wetlands rated as being of 'regional significance' but which were bordering on being rated at the national level. Since the process of rating the significance of individual wetlands is presently informal, an intermediate category is a useful way of indicating relative importance.

Regional

Of the 46 identified potential DIWA wetlands, 27 only met criteria 1 (a good example in a bioregion). In most cases these equated to an assessment as regional conservation significance. In the exceptions, the conservation significance was also influenced by other factors such as the national distinctiveness or lack of it. Although the *Finke Floodout Forest* has little species data to highlight its significance, it is a highly unusual wetland, which is why it was rated as 'national significance'. In contrast, the *Large Semi-permanent Waterholes of the Georgina River System (NT portion)* met DIWA criterion 3 as well as 1, due to the moderately documented refuge value for fish and birds. However, since the NT only holds a portion of the greater Diamantina River system, the significance level was rated as regional. The *Newhaven Lakes* were deemed to be likely to meet criterion 3 as wetland bird habitat but data were not available to test this. This aggregation also consists of an unusual variety of wetlands that are being managed for conservation. Accordingly we rated it as nationally important. One site was rated as of 'suspected regional importance' because there is currently no species data for it, only anecdotal reports.

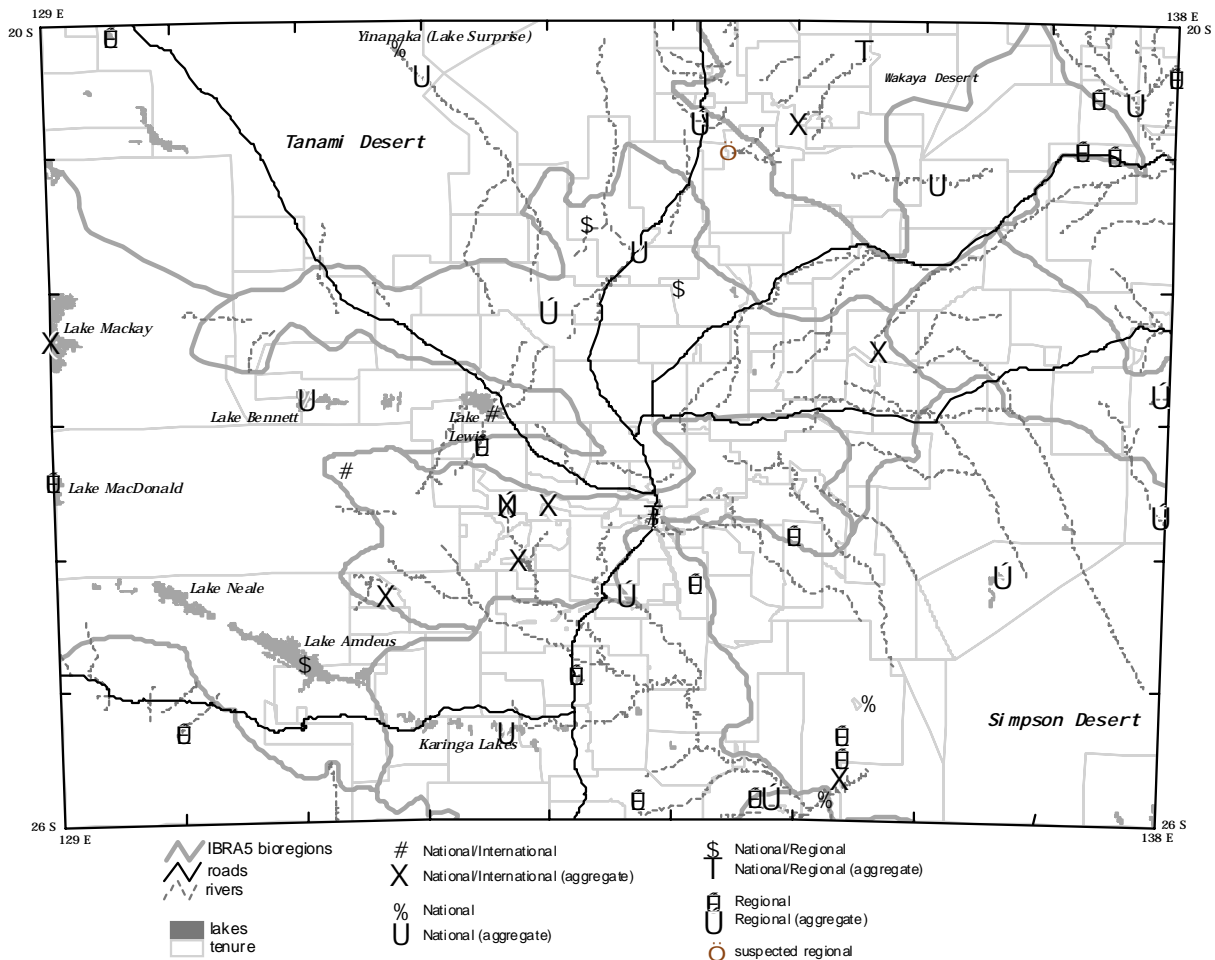


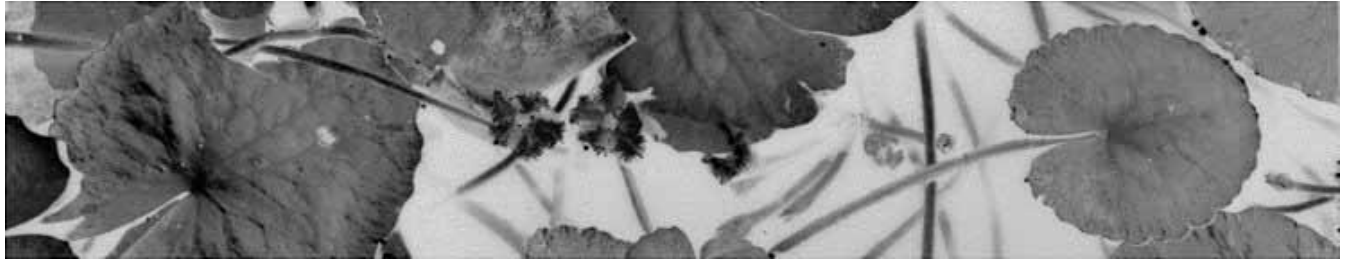
Figure 22. Map of identified 'important' wetlands.

Delineation of Important Wetlands

The mapping of individual wetlands varies in adequacy. Individual wetlands that are large enough to be mapped on 1:250,000 maps are usually reasonably well delineated. The floodout swamps of the Elkedra and Frew Rivers are notable exceptions and these have been mapped with remote sensing (see appendix 2). The components of the aggregate wetlands are generally not consistently mapped. The distributions of distinct zones or 'wetland types' with individual wetlands are not mapped.

Some of the sites could be much better delineated with additional aerial photograph and satellite image interpretation. Such mapping work has not been undertaken for individual wetlands.

Landowners should be consulted about the publication of maps showing detailed locations. Any such maps should be published with advice that land-holder/manger permission should be sought before wetlands are visited. This courtesy is important if effective cooperative conservation is to be implemented for wetlands outside of formal conservation reserves (off-park).



15. Summary of Wetlands by Bioregion and Comparison with other Parts of the Arid Zone

Scope

A summary of the wetlands of each bioregion is presented, including the following elements for each bioregion:

- a geographic description of the physiography of each bioregion including terrain and associated drainage patterns;
- a table of wetland types in the bioregion;
- a summary description for each of the potential Directory wetlands for the bioregion.

The tables of wetland type in each bioregion are based on a general rather than systematic analysis of data collated during the project. The tables show the occurrence of a wetland type with ticks: ✓. Possible occurrence is shown with a question mark: ?. Significant or widespread occurrence is shown by two drips. A meaningful numerical summary of the number and area of most wetland types is not currently possible.

15.1 Burt Plain Bioregion

Physiography

One of the distinguishing features of the Burt Plain Bioregion is the predominance of earthy, alluvial soils as opposed to sandplains and sand dunes. It also has a relatively high density of mountain ranges, in the east, north and west of the bioregion. The name of the bioregion comes from the plains to the north of Alice Springs, bisected by the Stuart Highway. The highest mountains are all in the west of the bioregion; with Mount Hay (1252 m) and Mount Chapple (1206) just a few km north of the West MacDonnells. To the north of these is the Reynolds Range with Mount Thomas at 1113m. Running parallel and to the north of the Reynolds Range are the Anmatjira and Yundurbulu Ranges, both with peaks over 1000m above sea level (asl) and with significant long-term freshwater springs. These ranges generate the major north flowing rivers of the study area: the Hanson River and the Lander River, with the Lander being the largest arid NT river that is not in the Lake Eyre Basin. The headwaters of the Lander River rise in mountains that exceed 450m above the plain, contributing to the energy levels and length of that river and possibly the frequency of flow. The mean annual rainfall isohyets show a regional area of relatively high rainfall in the area of the Reynolds, Anmatjira and Yundurbulu Ranges. However, there are no permanent natural waters in the Lander, despite the mountains, springs and anecdotal evidence that river flows are relatively frequent (M. Lines pers. comm.).

Running south from the Reynolds Range are Napperby Creek and also Gidyeya and Day creeks, carrying water only about 50km to Lake Lewis and the surrounding swamps. Mount Leichhardt is to the north of the Yundurbulu Range and has a dramatic profile; standing at the edge of the Tanami Desert at 1239m above sea level and about 550m above the plain. There are various smaller ranges in the north west of the Burt Plain Bioregion, including the Treuer Range, which generate minor drainages flowing north into the Tanami Desert and west and south into the Great Sandy Desert. In the north of the bioregion are various low ranges on either side of the Stuart Highway, including the Osbourne and Watt Ranges and the hills to the east and south of Barrow Creek. Some of these hills generate creeks that form the Taylor River; a minor river that floods out to the north of Barrow Creek. Some of the creeks feed the Hanson River and the associated Stirling Swamp and a great many others flood out into the plains without forming significant swamps. Other minor ranges in the Burt Plain Bioregion include the Jervois Range. Interestingly, one of the range areas of lowest relief is the most important for waterholes and springs: the Dulcie Ranges, which contain permanent rockholes and springs that allow fish to persist in the associated rivers (the Sandover and Plenty-Hay systems). There are various swamps in the Burt Plain Bioregion, the largest of which are associated with the Hanson and Sandover river systems.

Summary of Wetlands

Table 40. Preliminary table of wetland types in the Burt Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1211	Large Freshwater Lakes and Pans	✓
B1221	Small Freshwater Lakes and Pans	✓
B1222	Isolated Rock Holes	✓
B2111	Samphire Saline Swamps	✓ (semi-saline)
B2112	Non-Samphire Chenopod Saline Swamps	?
B2211	Wooded Swamps (Non-linear)	✓✓
B2212	Wooded Swamps (Linear/Riverine)	✓
B2221	Bluebush Swamps	✓
B2222	Lignum Swamps	✓
B2223	Other Shrubby Freshwater Swamps	?
B2231	Grassy Freshwater Swamps	?
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F0001	Bare Flood-prone Flat	✓
F0002	Wooded Flood-prone Flat	?
F0003	Shrubby Flood-prone Flat	?
Watercourses		
WU1201	Temporary Upland Waterholes	✓
WU2102	Non-Permanent but Long-term Spring-fed Upland Streams	✓
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1121	Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges	?
WL1122	Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges	?
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2003	Melaleuca Dominated Lowland Watercourses	?
WL2005	Unwooded Lowland Watercourses	✓?
Springs		
SU1	running upland springs – undetermined longevity	*
SU2201	Generally Wet Minor Springs and Seepages in Exposed Upland Terrain	✓
SU2202	Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry)	✓
SL1112	Temporary (generally dry) Running Freshwater Springs in Lowland Drainage Lines	?
SL1121	Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines	✓?
Subterranean (underground)		
U0001	Underground Water filled Spaces in Rock with Macroscopic Invertebrates	?
Artificial		
A1001	Dams Across Watercourses	✓
A1002	Excavated Dams/Tanks in Swamps and Pans	✓
A1003	Other excavations: quarries, borrow pits, mine pits	?
A2001	Excavated Dams Filled from Bores	?
A2002	Built-up Earth Tanks Filled from Bores	?
A2003	Minor Overflow from Bores	?
A2004	Open Metal/Concrete Tanks filled from Bores	✓
A3001	Sewage Ponds	?

Important Wetlands

Dulcie Ranges Springs and Waterholes

General Description: An area with a moderately large number of springs occurring in rocky ranges and supporting rare plants as well as contributing to the longevity of waterholes which are drought refuges for fishes and presumably also aquatic invertebrates. This site is an aggregation of individual wetlands.

Significance for Biodiversity Conservation: (National/International) An area important for regional diversity of wetland biota and the only example of a concentration of springs, permanent rockholes and riverine waterholes in the Burt Plain Bioregion. There are no other documented long-term waterholes in the Sandover River system. Several species of wetland plants occur that are typical of moister climates and many more that are rare or absent elsewhere in the bioregion. It is a refuge for fish in 2 separate river systems and may have a distinctive aquatic invertebrate fauna. The Ooratippra Creek catchment is the only place in the Burt Plain bioregion in which any native fishes other than Spangled Grunter (*L. unicolor*) occurs. The fishes of the Ooratippra Creek catchment are unlikely to be genetically distinct from the Georgina River populations due to occasional surface water connection of the Sandover to the Georgina.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 3

Ramsar Criteria for International Significance: ?1, ?3, ?4

Mudhut Swamp

General Description: A large wooded swamp

Significance for Biodiversity Conservation: (National/Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Narwietooma Lignum Swamp

General Description: A Lignum swamp surrounding a temporary lake

Significance for Biodiversity Conservation: (Regional) A good example of a lignum swamp that holds water for many months.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Pine Hill and Conniston Springs

General Description: Long-running (non-permanent) upland springs

Significance for Biodiversity Conservation: (Regional) examples of long term/non-permanent springs

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Stirling Swamp

General Description: A large wetland complex with areas of bare claypan, Lignum swamp, semi-saline samphire and temporary open water.

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 2, 3, 4, 5

Ramsar Criteria for International Significance: 2

Woodduck Swamp

General Description: A large wooded swamp with a central waterhole

Significance for Biodiversity Conservation: (National/Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

15.2 Central Ranges Bioregion

Physiography

The Central Ranges Bioregion straddles the NT, SA, WA border region, incorporating the neighbouring mountainous parts of SA and WA. The Mann Ranges extend from South Australia into the NT with several peaks over 1000m asl. They only generate one drainage system of moderate extent in the NT; being Britten-Jones Creek, which runs north from the South Australian Border, towards Uluru. Further north and west, the Petermann Ranges also rise to 1000m asl and generate several moderately long rivers and creeks. Most of these flood out to the north towards Lake Neale and Lake Amadeus in the Great Sandy Desert bioregion, with the exception of Docker River and Giles Creek which run into Western Australia. The Central Ranges Bioregion, although defined by tall mountains is generally less mountainous than either the MacDonnell Ranges or Davenport Murchison Ranges bioregions, with considerable areas of plains and sand dunes. There are also various small to medium swamps and claypans; particularly to the north and north-west of the Mann Ranges.

Summary of Wetlands

Table 41. Preliminary table of wetland types in the Central Ranges Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1211	Large Freshwater Lakes and Pans	?
B1221	Small Freshwater Lakes and Pans	✓
B1222	Isolated Rock Holes	✓
B2223	Other Shrubby Freshwater Swamps	✓
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F	undetermined Flood-prone Flat	?
Watercourses		
WU1201	Temporary Upland Waterholes	?
WU2201	Generally Dry (Temporary) Upland Channels	?
WL1121	Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges	?
WL1122	Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges	?
WL1202	Temporary (Generally Dry) Lowland Waterholes	?
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2003	Melaleuca Dominated Lowland Watercourses	?
WL2005	Unwooded Lowland Watercourses	?
Springs		
SU1	undetermined running upland springs	?
SU2112	Non-permanent Sheltered Freshwater Minor Springs and Seepages	?
Subterranean (underground)		
U0001	Underground Water filled Spaces in Rock with Macroscopic Invertebrates	?
Artificial		
A3001	Sewage Ponds	?

Important Wetlands

None documented. This is a reflection on the poor level of knowledge of this bioregion.

15.3 Channel Country Bioregion

Physiography

The Channel Country Bioregion predominantly occurs in Queensland with a significant part in South Australia and only small portions in the NT and New South Wales. Thackway and Cresswell (1995) describe the bioregion as comprised of low hills; forb-fields and Mitchell Grass downs with braided river channels of Coolabah and Lignum and Chenopodium species (presumably northern Bluebush – *C. auricomum*). The NT portion is not representative of the whole bioregion because it lacks the major braided channel networks associated with rivers such as the Diamantina and Cooper Creek. In the NT portion there are large areas of undulating plains dominated by Gidgea Wattle. There are areas of indistinct undulating hills, some isolated more distinct hills and several low ranges including the Tarlton Range (up to 375 m asl), the Umberumbera Hills (c. 300 m asl) and the larger Toko Ranges on the Queensland Border (c. 330 m asl). Many of the creeks, running off the low hills, flood out onto the adjacent flats. The creeks in the north eastern part of the NT portion are tributaries to the Georgina River, whilst in the south the creeks running south off the Toko Ranges and Umberumbera Hills form the Field River and its major tributary, Marqua Creek. The Field River floods out into the northern Simpson Desert, with the floodout extending into Queensland. Wetlands include a number of large swamps of various types including Bluebush, at least two permanent springs and waterholes in the Toko Ranges, various claypans and the Field River floodout swamps. There are no wetlands on the scale of the massive Copper Creek and Diamantina floodplains.

Summary of Wetlands

Table 42. Preliminary table of wetland types in the Channel Country Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1.1	undetermined saline open water bodies	?
B1221	Small Freshwater Lakes and Pans	✓
B2212	Wooded Swamps (Linear/Riverine)	✓
B2221	Bluebush Swamps	✓✓
B2232	Herbaceous Swamps (non-grassy)	?
Flats		
F0002	Wooded Flood-prone Flat	✓
Watercourses		
WU1201	Temporary Upland Waterholes	✓
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1111	Permanent Lowland Waterholes at the Base of Ranges	✓?
WL1123	Large Turbid Near-Seasonal Lowland Waterholes	?
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2004	Acacia Dominated Lowland Watercourses	?
WL2005	Unwooded Lowland Watercourses	?
Springs		
	Springs of undetermined character	✓ (Toko Ranges)
SL2111	Freshwater Minor Springs and Seepages in Lowland Drainage Lines	? (possibly under 2 dams)
Artificial		
A1001	Dams Across Watercourses	✓✓ (includes Jervois Mine Dam)

Important Wetlands

Small Spring-fed Waterholes of the Toko Ranges

General Description: Two or three shallow spring-fed waterholes at the base of low sandstone ranges

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 2, 3

Ramsar Criteria for International Significance: not assessed

15.4 Davenport Murchison Ranges Bioregion

Physiography

The Davenport Ranges and the adjacent Murchison Ranges form the second largest range system in the arid NT, based on area not height. These two range systems are encompassed in the Davenport Murchison Ranges Bioregion (recently separated from the Tanami Bioregion). This broad series of low ranges has a predominant height of 500-600 m asl but rarely exceeds 200 m above the surrounding plain. They contain many long lasting waterholes, including many of the largest in the arid NT. Jones and Quinlan (1962, p.150) record that some are permanent and Jephcott (1956) indicates permanent or semi-permanent waterholes on the Elkedra River, however there is no documentation of the extent this is due to groundwater discharge (spring-fed). A number of large rivers are produced by the ranges, all of which flood out into the surrounding plains, and three of which generate medium to long lasting swamps. The southern extent of the ranges contributes some minor creeks into the Sandover River. To the north-east the bioregion includes the broad sand plain of the Wakaya Desert, which has similar vegetation to the adjoining Tanami Bioregion. The Wakaya Desert has very few drainage features, with part of the Frew River floodout penetrating the desert as Walkabout Creek. The Elkedra River is the longest of the Davenports rivers, running east into the eastern portion of the Tanami Bioregion, but no longer connecting to the Georgina River system.

Abundance and Persistence of Waterholes

The abundance of waterholes and isolated drainage systems is a very important biological characteristic of the Davenport Murchison Ranges Bioregion. Little is documented about the persistence of the various rockholes in the ranges. However, little is documented about the persistence of the various rockholes in the ranges. The majority of the permanent waterholes are in the Whistleduck Creek and Frew River systems. There are some large and long lasting waterholes in other drainages including the Elkedra River and Gosse River system.

The waterholes of the bioregion can be usefully divided into those that occur in the rocky ranges and are often bounded by rock walls on at least one side, and those that are out of the ranges. The lack of substantial relief means that stream gradient does not usefully distinguish these two groups. Compared to other bioregions, there is a high abundance of the latter type of waterhole which loosely fits in the 'lowland waterhole' wetland type. Many if not most of these are a result of bedrock confining the water and possibly promoting scour. Some are very large (> 1 km) long and very long lasting.

Johnson *et al.* proposed an area of the Davenport and Murchison ranges as suitable for a national park, noting that it contained numerous rockholes and waterholes, consisting of those marked on topographic maps and additional ones encountered during the survey. However, in this current inventory, no records were found of the locations of those additional waterholes. Their survey visited 48 of rockholes/waterholes on the ground and observed others from aerial survey. Johnson *et al.* (1994, p.2) note that '38 rockhole and waterholes' were recorded in their southern survey block which contains the catchments of Whistleduck Creek and the Frew River. Fleming *et al.* (1983) refer to a large unnamed rockhole in the Murchison Ranges but do not give coordinates. Johnson *et al.* (1984, p.15) refer to 'several large and deep rockholes on Turkey Creek' in the Murchison Range and name three permanent waterholes in Whistleduck Creek stating that (at least) one is spring fed. The Elkedra River has two permanent waterholes of undocumented character and several other large and long lasting waterholes, of which some are semi-permanent (R. Driver pers. comm.).

Summary of Wetlands

Table 43. Preliminary table of wetland types in the Davenport Murchison Ranges Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1221	Small Freshwater Lakes and Pans	?
B2211	Wooded Swamps (Non-linear)	✓
B2212	Wooded Swamps (Linear/Riverine)	✓
B2221	Bluebush Swamps	?
B2223	Other Shrubby Freshwater Swamps	✓
B2231	Grassy Freshwater Swamps	?
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F0002	Wooded Flood-prone Flat	✓
F0003	Shrubby Flood-prone Flat	✓
Watercourses		
WU1111	Permanent Upland Waterholes	?
WU1121	Non-Permanent but Long-term Upland Waterholes	?
WU1201	Temporary Upland Waterholes	✓
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1111	Permanent Lowland Waterholes at the Base of Ranges	✓?
WL1112	Permanent Lowland Waterholes in Gaps and Gorges	✓?
WL1113	Other Permanent Lowland Waterholes	✓?
WL1121	Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges	✓
WL1122	Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges	✓
WL1123	Other Generally Wet Non-permanent Lowland Waterholes	✓
WL1124	Large Turbid Near-Seasonal Lowland Waterholes	✓
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2003	Melaleuca Dominated Lowland Watercourses	✓✓
WL2004	Acacia Dominated Lowland Watercourses	?
WL2005	Unwooded Lowland Watercourses	✓
Springs		
Artificial		various not well documented
A1001	Dams Across Watercourses	?
A1002	Excavated Dams/Tanks in Swamps and Pans	?
A2001	Excavated Dams Filled from Bores	?
A2002	Built-up Earth Tanks Filled from Bores	?
A2004	Open Metal/Concrete Tanks filled from Bores	?

Important Wetlands

Frew River Floodout Swamps

General Description: A series of wooded swamps inundated principally by the Frew River

Significance for Biodiversity Conservation: (National/Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 2, ?3

Ramsar Criteria for International Significance: not assessed

Permanent Waterholes of the Davenport Ranges National Park

General Description: Permanent large waterholes in low dissected sandstone ranges which provide an important drought refuge for seven naturally occurring fish species, as well as waterbirds and terrestrial fauna. There are also some long-lasting waterholes on neighbouring pastoral leases and Aboriginal freehold; however, the majority of the large permanent waterholes are in the conservation reserve. This site is an aggregation of individual Significance for Biodiversity Conservation: (National/International) The area is nationally significant as a drought refuge for fishes, of which one species may be endemic to the area. The waterbodies are also regionally significant for waterbirds and are no doubt important for terrestrial fauna as well. There is a moderate to good case for international importance based on the biodiversity of fishes in the Davenport Murchison ranges bioregion. The Davenports *Mogurnda* (*Mogurnda* sp.) may be determined as a distinct species or subspecies. The glass fish (*Ambassis* sp.) is also under taxonomic review. The other species definitely have a much broader distribution but due to their isolation the Davenports populations may have some genetic distinctiveness. The flora of the permanent and semi-permanent waterholes is distinctive but few species have special conservation value in their own right. The aggregated site is undoubtedly important as a habitat for waterbirds and may act as a refuge for the less mobile species; however, there is insufficient data to estimate numbers. At the scale of IBRA bioregions, the aggregated site is also important under criterion 1, as an example of permanent rockholes in the bioregion and also in the context of the neighbouring bioregions.

Significance for Biodiversity Conservation: (National/International)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 2, 3, (possibly 4)

Ramsar Criteria for International Significance: ?1, 2, 3, ?3

15.5 Finke Bioregion

Physiography

The Finke Bioregion is highly diverse and extends from the outskirts of Alice Springs to South Australia; and from the eastern shores of Lake Amadeus to the western part of the Simpson Desert. It is dominated by flat and undulating plains with significant areas of saline lakes and sand dunes and occasional, relatively low ranges. The Finke River system and associated floodplains are a dominant feature. The inclusion of large areas of sand dunes outlying from the main Simpson Desert is mainly due to the bioregion boundary approximating the somewhat indistinct eastern edge of the basin of the Finke River. The Finke Bioregion has many other sand dune areas, well removed from the Simpson Desert. The bioregion has only isolated low hills and ranges. They include Mount Ebenezer, Mount Connor, part of Deep Well Range, the low, eastern end of the James Range. The Beddome Range, on the South Australian border, generates the last two significant tributaries of the Finke River: Goyder River and Coglin Creek (also called Charlotte Waters). The Beddome Range is much more rounded than most of the arid NT ranges which are mostly narrow and steep or low and flat topped (beveled). The wetlands of the bioregion include the Finke River system, with various waterholes and floodplain swamps. However the numerous saline and semi-saline lakes of the Karinga Creek and Lake Amadeus system totally dominate the total count and area of wetlands. Added to these are various, springs claypans and swamps.

Summary of Wetlands

Table 44. Preliminary table of wetland types in the Finke Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1111	Highly Saline Lakes (Salt Lakes)	✓
B1121	Saline Lakes / Samphire Swamps	✓
B1122	Saline Lakes / Non-Samphire Chenopod Swamps	✓
B1211	Large Freshwater Lakes and Pans	✓
B1221	Small Freshwater Lakes and Pans	✓
B1222	Isolated Rock Holes	?
B2111	Samphire Saline Swamps	✓
B2112	Non-Samphire Chenopod Saline Swamps	✓
B2211	Wooded Swamps (Non-linear)	✓
B2212	Wooded Swamps (Linear/Riverine)	✓
B2222	Lignum Swamps	✓
B2223	Other Shrubby Freshwater Swamps	✓
B2231	Grassy Freshwater Swamps	✓
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F0002	Wooded Flood-prone Flat	?
F	undetermined Flood-prone Flat	?
Watercourses		
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1121	Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges	✓ (not necessarily at the base of ranges)
WL1123	Other Generally Wet Non-permanent Lowland Waterholes	✓
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2005	Unwooded Lowland Watercourses	?
WL2007	Highly Saline Channels	✓

Springs		
SL1111	Generally Running Freshwater Springs in Lowland Drainage Lines	✓
SL2221	Long-term Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline	✓
SL2222	Temporary Springs on Salt Lake Margins and Lake Beds - Saline/Semi-saline (generally dry)	✓
Subterranean (underground)		
U0001	Underground Water filled Spaces in Rock with Macroscopic Invertebrates	✓
Artificial		
A1001	Dams Across Watercourses	✓
A1002	Excavated Dams/Tanks in Swamps and Pans	✓
A1003	Other excavations: quarries, borrow pits, mine pits	✓
A2004	Open Metal/Concrete Tanks filled from Bores	✓
A3001	Sewage Ponds	?

Important Wetlands

Ettenia Spring

General Description: A spring with flowing surface water for several hundred metres of sandy minor creek.

Significance for Biodiversity Conservation: (Regional) An unusual, almost spring, possibly unique in the Finke Bioregion. No rare plants were recorded. No fish were recorded and not big enough to be of great significance for wetland birds.

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Kangaroo Dam Swamp

General Description: A large wooded swamp

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Karinga Creek Paleodrainage System

General Description: A collection of saline lakes and swamps.

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria:1,4,6

Ramsar Criteria for International Significance: not assessed

Salt Creek Lake

General Description: A large and unusually long-lasting temporary lake

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

15.6 Great Sandy Desert

Physiography

The Great Sandy Desert bioregion is the second largest in Australia and is named after the vast northern desert of West Australia. The NT portion is characterised by vast expanses of sand dunes and vast salt lakes plus areas of sand plains, occasional alluvial plains, and various swamps and claypans. The area has very few hills or ranges but includes the internationally known Uluru (Ayers Rock) and Kata-Tjuta (The Olgas) which rise nearly 500m above the plain (Mt Olga 1066 m), as well as the Kintore Range and Ehrenberg Range, both approaching 900m above sea level, the Cleland Hills (c. 800m asl), and various ranges to the north of the lake system from Lake Bennett to Lake Lewis, with the tallest, Central Mount Wedge, exceeding 1000m. There are no major rivers emanating from any of these ranges; only minor creeks which travel short distances before dissipating into the surrounding dunes and plains. The only creeks of more than a few kilometres, intrude from surrounding bioregions, including Ethel Creek which emanates from the Treuer Range, Napperby Creek, which runs into Lake Lewis from the Reynolds Range and several that emanate in the Petermann Ranges. The other large salt lakes which characterise the NT portion of Great Sandy Desert Bioregion are Lake Neale, Lake Amadeus, Lake Mackay (Australia's 4th biggest lake), Lake White and Lake MacDonald. None of these is directly fed by major rivers emanating from ranges and the last three all straddle the NT-WA border. The salt lakes associated with Karinga Creek are in the Finke Bioregion, although they have much in common with those of the Great Sandy Desert Bioregion. There are few documented springs or rockholes in the Great Sandy Desert Bioregion. A great many water sources are known to Aboriginal people and may include caves in calcareous rocks. Some of these may be permanent. Low *et al.* (1986) notes the presence of freshwater springs around the edge of Lake Lewis. These are presumed to be non-permanent.

Summary of Wetlands

Table 45. Preliminary table of wetland types in the Great Sandy Desert Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1111	Highly Saline Lakes (Salt Lakes)	✓✓
B1121	Saline Lakes / Samphire Swamps	✓
B1122	Saline Lakes / Non-Samphire Chenopod Swamps	?
B1211	Large Freshwater Lakes and Pans	?
B1221	Small Freshwater Lakes and Pans	✓✓
B1222	Isolated Rock Holes	✓ (possibly abundant)
B2111	Samphire Saline Swamps	✓
B2112	Non-Samphire Chenopod Saline Swamps	?
B2121	Saline Grassy Swamp	?
B2212	Wooded Swamps (Linear/Riverine)	?
B2223	Other Shrubby Freshwater Swamps	?
B2231	Grassy Freshwater Swamps	✓
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F0004	Grassy Flood-prone Flat	?
Watercourses		
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1121	Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges	✓ (e.g. Muranji Rockhole)
WL2001	Major Wooded Watercourses	?
WL2002	Minor Lowland Wooded Watercourses	?
WL2003	Melaleuca Dominated Lowland Watercourses	✓
WL2007	Highly Saline Channels	✓?
Springs		

SL2111	Freshwater Minor Springs and Seepages in Lowland Drainage Lines	?
SL2211	Freshwater Lowland Springs and Seepages not in Drainage Lines	✓
Subterranean (underground)		
U0001	Underground Water filled Spaces in Rock with Macroscopic Invertebrates	✓?
Artificial		
	various stock waters – type not documented	✓
A3001	Sewage Ponds	?

Important Wetlands

Lake Amadeus

General Description: A large shallow salt lake.

Significance for Biodiversity Conservation: (National/Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Lake Lewis

General Description: A large, relatively deep temporary saline lake with a highly crenellated shoreline and numerous islands. The lake and surrounding swamps are also widely known as Napperby Lakes. The lake is unusual among arid NT salt lakes (and also Western Australian ones) in that it is fed directly by a relatively large river (Napperby Creek) and in that it is populated by fish following inundation and until salinity rises as it dries back.

Significance for Biodiversity Conservation: (National/International) Periodically supports significant populations of water birds. Aerial survey for about 30 minutes on 6 Sept 2001, recorded 8 species and a count of 13,170 birds. A total of 13 wetland bird species is known from the lake. At the time of survey the surface waters had receded considerably since the lake was filled in February 2000. It is highly likely that the Ramsar threshold number of 20,000 birds is exceeded during major inundations which seem to occur in the order of four times per century. The likely value of this site for occasional but substantial breeding by wetland birds qualifies the wetland under criterion 3 of the Directory criteria (habitat for animal taxa at a vulnerable stage in their life Directory of Important Wetlands in Australia (DIWA) Criteria:1, 3

Ramsar Criteria for International Significance: ?1, ?5

Lake Mackay

General Description: The fourth largest lake in Australia, Lake MacKay is a vast salt lake with numerous islands and smaller freshwater swamps and pans in the surrounding sandplains and dunes. Inundation, although infrequent, can be moderately long lasting (> 6 months). This combined with the islands, provides important breeding habitat for waterbirds, as shown by breeding activity recorded in October 2001 (e.g. 4,400 immature Banded Stilts)

Significance for Biodiversity Conservation: (National/International) The site is likely to be an occasional major breeding location for the Banded Stilt. A population of at least 12,000 Banded Stilt was present at Lake Mackay during an aerial survey. Given that the population of this endemic species is estimated at only about 206,000 (Marchant & Higgins 1993), Lake Mackay is clearly a nationally significant site for the conservation of the species. Its significance for the species is enhanced by the absence of large colonies of Silver Gulls which are a significant predator of Banded Stilt hatchlings. Lake Mackay also supports large numbers of ducks and terns. Although the lake only episodically provides large areas of waterbird habitat it is of international significance; meeting the criteria set up under the Ramsar Convention.

Directory of Important Wetlands in Australia (DIWA) Criteria:1 4, ?5

Ramsar Criteria for International Significance: 1, ?2, ?4, ?5, ?6

Lake MacDonald

General Description: Large saline lake

Significance for Biodiversity Conservation: (Regional) poorly known. Presumed value for wetland birds

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Lake Neale

General Description: Large saline lake

Significance for Biodiversity Conservation: (Regional) poorly known. Presumed value for wetland birds

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Newhaven Lakes

General Description: An aggregation of various wetland types: large salt lakes, saline/gypseous swamps, claypans and freshwater swamps

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: ?1

15.7 MacDonnell Ranges Bioregion

Physiography

The largest group of mountain ranges are those referred to collectively as the MacDonnell Ranges, which run approximately east and west from Alice Springs. These ranges and those extending from Alice Springs south west to Watarrka (Kings Canyon) and to the north east to the Harts Range, define the MacDonnell Ranges Bioregion. They are tall enough to precipitate considerable rainfall and give rise to the majority of the larger rivers, including the Finke River system, the Todd and Hale Rivers and Illogwa Creek; all running to the south east. The bioregion also provides a significant part of the catchments of the Sandover and Plenty River Systems. The highest parts of the bioregion are in the West MacDonnells, with many parts over 1200m asl and up to 900 m above the surrounding plain. The highest peaks in the west are all more or less at the northern edge of the bioregion and the northern edge of the Amadeus sedimentary Basin. They include Mount Zeil (1531 m), Mount Edward (1423 m) near Papunya, Mount Sonder (1380 m) and Mount Giles (1389 m). The largest discrete range of mountains is the Chewings Range of which Mount Giles is the highest point. The other ranges are generally much less elevated, with the high points of the East MacDonnells ranging from about 800 – 1150 m above sea level. The Harts Range at the north east edge of the MacDonnell Ranges Bioregion has a predominant height of about 1000 m with the tallest peak being Mount Brassey at 1203 m. The Strangways Range, to the north of Alice Springs, also have a predominant height of about 1000 m. The Krichauff, James and George Gill Ranges, in the south west of the bioregion, are all below 1000 m. There are various springs and permanent or long-term waterholes associated with the MacDonnell Ranges (in the broad sense) and relatively few non-riverine wetlands, such as swamps and claypans.

Summary of Wetlands

Table 46. Preliminary table of wetland types in the MacDonnell Ranges Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1221	Small Freshwater Lakes and Pans	✓
B2211	Wooded Swamps (Non-linear)	✓ uncommon
B2212	Wooded Swamps (Linear/Riverine)	✓
B2221	Bluebush Swamps	✓ uncommon
B2222	Lignum Swamps	✓
B2223	Other Shrubby Freshwater Swamps	✓
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F0002	Wooded Flood-prone Flat	✓ Mt Benstead Ck Red Gum Forest
F	undetermined Flood-prone Flat	?
Watercourses		
WU1111	Permanent Upland Waterholes	✓
WU1121	Non-Permanent but Long-term Upland Waterholes	✓
WU1201	Temporary Upland Waterholes	✓
WU2101	Permanent Spring-fed Upland Streams	✓
WU2102	Non-Permanent but Long-term Spring-fed Upland Streams	?
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1111	Permanent Lowland Waterholes at the Base of Ranges	✓
WL1112	Permanent Lowland Waterholes in Gaps and Gorges	✓
WL1121	Generally Wet Non-permanent Lowland Waterholes at the Base of Ranges	✓
WL1122	Generally Wet Non-permanent Lowland Waterholes in Gaps and Gorges	✓ ?
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓

WL2002	Minor Lowland Wooded Watercourses	✓
WL2003	Melaleuca Dominated Lowland Watercourses	✓
WL2005	Unwooded Lowland Watercourses	?
Springs		
SU1101	Permanent Running Upland Freshwater Springs	✓
SU1102	Generally Wet Running Upland Springs (non-permanent)	?
SU1211	Temporarily Running (generally dry) Freshwater Upland Springs	✓
SU1	undetermined running upland springs	✓
SU2111	Permanent Sheltered Freshwater Minor Springs and Seepages	✓
SU2112	Non-permanent Sheltered Freshwater Minor Springs and Seepages	?
SU2201	Generally Wet Minor Springs and Seepages in Exposed Upland Terrain	?
SU2202	Temporary Minor Springs and Seepages in Exposed Upland Terrain (generally dry)	?
SL1111	Generally Running Freshwater Springs in Lowland Drainage Lines	✓
SL1121	Generally Running Saline/Semi-saline Springs in Lowland Drainage Lines	✓
SL1122	Temporary (generally dry) Running Saline/Semi-saline Springs in Lowland Drainage Lines	?
SL2111	Freshwater Minor Springs and Seepages in Lowland Drainage Lines	✓
SL2121	Saline/Semi-saline Minor Springs and Seepages in Lowland Drainage Lines	✓
SL2223	Mound Springs – Saline/Semi-saline	✓
Artificial		
A1001	Dams Across Watercourses	✓
A2004	Open Metal/Concrete Tanks filled from Bores	✓
A3001	Sewage Ponds	✓
A3002	Swamps Created/Modified By Treated Sewage	✓

Important Wetlands

One of the sites already in the Directory should be replaced with two new sites (subject to landholder approval). The existing site is NT002 *Finke River Headwater Gorges System* which is superseded by the proposed sites NT-potential-1 *Permanent and Long-term Waterholes of the Finke River System* and NT-potential-2 *Chewings Range Permanent Springs*. These largely have distinct biodiversity values, apart from the upper Serpentine Pool in the Heavitree Range, which is fed by an external spring.

Alice Springs Sewage Ponds

General Description: Sewage Treatment Ponds

Significance for Biodiversity Conservation: (National/International)

Directory of Important Wetlands in Australia (DIWA) Criteria:3

Ramsar Criteria for International Significance: not assessed

Chewings Range Permanent Springs

General Description: A number of permanent flowing springs emanating from a high quartzite range and supporting a distinctive flora and fauna and relictual fern populations in particular. This site is an aggregation of individual wetlands. Individual wetlands have not been documented sufficiently for an accurate estimate of the combined surface area. **If approved, this site will replace the Finke River Headwater Gorges site already listed in A Directory of Important Wetlands in Australia.**

Significance for Biodiversity Conservation: (National/International) The assemblages of flora and fauna are unique in central Australia and important for regional biodiversity.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: 1, 3

George Gill Range Springs and Rockholes

General Description: A series of gullies draining the southern side of the George Gill Range contain permanent seepage springs and long-term rockholes that support a distinctive suite of relictual flora and fauna. This site is an

aggregation of individual wetlands. Individual wetlands have not been documented sufficiently for an accurate estimate of the combined surface area.

Significance for Biodiversity Conservation: (National/International) The permanent seepages and long-term rockholes of the George Gill Range have a distinctive assemblage of invertebrates and various wetland plants which are rare in the arid NT. The wetlands are accordingly important for regional diversity of wetland biota. They are different from similar wetlands in the West MacDonnell Ranges in the invertebrate assemblage, the isolation from a major drainage network (and associated absence of fish) and in some of the plant species including the endemic *Hydrocotyle*A39600 Watarrka and the aquatic *Vallisneria annua*.

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: 1, 3

Illparpa Valley Wetlands

General Description: An aggregation of various wetland types: sewage ponds, Typha swamp, claypans, Wooded swamp and long-lasting riverine waterholes.

Significance for Biodiversity Conservation: (National/Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1, 3, 4, 5

Ramsar Criteria for International Significance: not assessed

Ormiston – Glen Helen Mound Springs

General Description: Semi-saline springs with varying degrees of mound formation

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Palm Valley Area Springs, Rockholes and Palm Groves

General Description: Long-term and possibly permanent springs, shallow rockpools and groves of Palm Valley Palm in tributaries to the Finke River; principally Palm Creek and Little Palm Creek catchments. The majority of the important wetland areas are in Finke Gorge National Park. Two small populations of palms occur in tributaries to the north of the park and a seepage area and rockpool occur upstream of the park boundary; all on Ntaria Aboriginal Land Trust. Additional populations of the Palm Valley Palm occur in the Finke River, extending about 30km to the SSE. However, the populations in the main Finke River are not included in this wetland site. The seepage springs and associated swamps and pools are clearly wetland features, although small. The groves of Palm Valley Palm all occur in drainage lines and so may also be considered wetland features, even though they are dependant on groundwater discharge which often has no expression as surface water flow or saturated soil. In some places there are deep crevices in the exposed bed rock, which may be important micro-habitats for invertebrates and some fishes. This site is an aggregation of individual wetlands. The individual wetlands have not been mapped at a sufficiently fine scale to allow an accurate measurement of their combined surface area.

Significance for Biodiversity Conservation: (National/International) The area is important for global and regional biodiversity of wetland plants, with the core populations of the endemic *Livistona mariae* subsp *mariae* (Palm Valley Palm). It also contains important populations of regionally rare wetland plants, and is thus important for maintaining regional biodiversity. The small long-term rockpools are an important adjunct to the drought refuge provided by the eight relatively large permanent waterholes of the Finke River system.

Directory of Important Wetlands in Australia (DIWA) Criteria:1, 3, 4, 5

Ramsar Criteria for International Significance: 1, 2, 3, ?4

Permanent and Long-term Waterholes of the Finke River System

(replacing Finke River Headwater Gorges)

General Description: There are eight large waterholes in the Finke River System which have never been known to dry out and are considered permanent. These, along with various smaller permanent waterholes and non-permanent but long-term waterholes, provide a drought refuge for nine species of native fish of which three are endemic to the Finke River system. This site is an aggregation of individual wetlands. Individual wetlands have not been documented sufficiently for an accurate estimate of the combined surface

Significance for Biodiversity Conservation: (National/International) The only natural permanent waters in the

bioregion, these waterbodies are important drought refuges for many species in addition to fishes due to the aridity of the general Directory of Important Wetlands in Australia (DIWA) Criteria:1, 2, 3, 4, 5

Ramsar Criteria for International Significance: 1,2,3,4,7

Rainbow Valley Claypans

General Description: Two large flat claypans

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Ringwood Bluebush Swamp

General Description: A large swamp with Northern Bluebush (*Chenopodium auricomum*) and Lignum (*Muehlenbeckia florulenta*)

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Talipata Spring

General Description: A permanent flowing freshwater spring with associated short running stream.

Significance for Biodiversity Conservation: (National/International) Three species of relictual mesic ferns and a relictual invertebrate occur, all indicating the permanence of the spring.

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: 3

15.8 Mitchell Grass Downs Bioregion

Physiography

The Mitchell Grass Downs Bioregion is the most heterogeneous and flattest of the bioregions in the arid NT being characterised by plains of generally very low relief. It extends a long way into Queensland with roughly a third of it in the NT. Only a much smaller part is in the arid NT as defined for the wetlands inventory. The arid NT portion is clearly delineated from the adjoining Tanami bioregions by the soils. Those on the Mitchell Grass Downs side are predominantly of two types of moderate to heavy texture ('black soil' clays and 'red soil'). The soils of the neighbouring Tanami bioregion are predominantly sandy. In the south the NT portion joins to the Channel Country Bioregion with which the boundary is less distinct. The typical wetlands of the bioregion are waterholes in the Georgina River system, Bluebush swamps, plus some grassy swamps. There are few claypans. The rivers of the Georgina system have large waterholes, some of which are semi-permanent. There are two large Coolabah swamps on the edge of the bioregion at or near the boundary with the spinifex dominated sand plains of the Tanami bioregion, which are unusual in their relative isolation from major rivers. One is presumed to fill from overflow of the Rankin River and the other from the Sandover Floodout. The vast flood-prone flats of the lower Sandover River floodout are included in the Mitchell Grass Downs Bioregion.

Summary of Wetlands

Table 47. Preliminary table of wetland types in the Mitchell Grass Downs Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1221	Small Freshwater Lakes and Pans	✓
B2212	Wooded Swamps (Linear/Riverine)	✓
B2221	Bluebush Swamps	✓
B2222	Lignum Swamps	✓
B2231	Grassy Freshwater Swamps	✓
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F	undetermined Flood-prone Flat	?
Watercourses		
WL1113	Other Permanent Lowland Waterholes	?
WL1123	Large Turbid Near-Seasonal Lowland Waterholes	✓✓
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2003	Melaleuca Dominated Lowland Watercourses	?
WL2004	Acacia Dominated Lowland Watercourses	✓
WL2005	Unwooded Lowland Watercourses	✓
Artificial		
A1001	Dams Across Watercourses	✓
A2002	Built-up Earth Tanks Filled from Bores	✓
A3001	Sewage Ponds	?

Important Wetlands

Blue Bush Swamp (Burrumurra)

General Description: A very large Northern Bluebush (*Chenopodium auricomum*) swamp.

Significance for Biodiversity Conservation: (Regional) Presumed value for wetland birds and plants. There are

several similar large swamp further north in this bioregion.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Large Semi-permanent Waterholes of the Georgina River System (NT portion)

General Description: An aggregation of long-lasting, semi-permanent large turbid waterholes

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 3

Ramsar Criteria for International Significance: not assessed

Sandover Highway Wooded Swamp

General Description: A large wooded swamp

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Note: This wetland lies on the edge of clay plains. The boundary between the clay plain and the sandplain is the bioregion boundary. This wetland is actually located within the mapped IBRA5 Tanami bioregion; however, the mapping is slightly inaccurate. We consider it to be in the MGD bioregion.

Yellow Hole Bore Swamp

General Description: A large grass dominated swamp

Significance for Biodiversity Conservation: (Regional) An unusual wetland type.
(note very limited survey; 'grassy swamp' may not be the dominant character)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

15.9 Simpson-Strzelecki Dunefields Bioregion

Physiography

The NT portion of Simpson-Strzelecki Dunefields Bioregion is dominated by the vast Simpson Desert, characterised by parallel sand dunes of various heights. Despite this, the bioregion has a number of impressive range systems in its north-west part, closest to Alice Springs. These ranges are generally very steep but are low and narrow and harbour no large rockholes and do not generate any large rivers. They do act as barriers to water movement and have some control on past and present courses of the Hale and Todd Rivers and their floodouts. The ranges include the Train Hills, Collins Range and Arookara Range that form the north east limit to the Simpson Desert. The Pillar and Rodinga ranges rise out of the north-west part of the desert as do a number of minor ranges and hills further south and west. The Simpson Desert is the driest portion of the NT and yet it contains a surprising diversity of wetland types. In between the ranges in the north west of the bioregion are several swamps including some artificial ones plus numerous claypans. The northern part of the Simpson Desert includes the floodouts of several large rivers, with some associated swamps. Also in the north are several areas of large claypans and saltlakes. There are inter dune claypans and swamps scattered across the desert and some other large lakes or pans in the far south east corner of the NT. In the western part of the bioregion, the Simpson Desert is fringed by and interspersed with gibber plains and occasional low rocky hills and associated with these are a variety of swamps and claypans. One of the largest wetland systems in the arid NT, the floodout of the Finke River, cuts into the Simpson Desert near the South Australian border, with a dense scrubby 'floodout forest', numerous inter dune swamps and various major and minor channels.

The landforms and vegetation of the Simpson Desert are broadly described by Purdie (1984).

Summary of Wetlands

Table 48. Preliminary table of wetland types in the Simpson-Strzelecki Dunefields Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1121	Saline Lakes / Samphire Swamps	✓
B1211	Large Freshwater Lakes and Pans	✓
B1221	Small Freshwater Lakes and Pans	✓
B2221	Bluebush Swamps	✓✓
Flats		
F	undetermined Flood-prone Flat	?
Watercourses		
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2005	Unwooded Lowland Watercourses	✓?
Artificial		
	Various stock waters	✓
A2005	Rogue Bores	✓ (McDills – rehabilitated but still flowing)

Gibson and Cole (1985a) report substantial impacts from camels and rabbits in the northern Simpson Desert salt lakes.

Important Wetlands

Casuarina Swamp

General Description: A large swamp dominated by Northern Bluebush and Swamp Canegrass

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 4, 5

Ramsar Criteria for International Significance: not assessed

Indemina Swamp

General Description: Large swamp, mostly unwooded, but areas of open Coolabah woodland.

Significance for Biodiversity Conservation: (Regional) Various wetland plants recorded and reports of large numbers of waterbirds.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Indinda Swamp

General Description: A very large Northern Bluebush (*Chenopodium auricomum*) swamp with catchment from adjacent gibber and low rocky hills.

Significance for Biodiversity Conservation: (Regional) birds & plants

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

North Eastern Simpson Desert – Field River Floodout and other swamps

General Description: Flood out swamps where the Field River runs into the northern Simpson Desert and a concentration of Bluebush swamps in the adjacent area

Significance for Biodiversity Conservation: (Regional) Various wetland plants occur. The area has presumed habitat value for wetland birds but was dry when surveyed.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1?

Ramsar Criteria for International Significance: not assessed

Northern Simpson Desert Area Lakes

General Description: Moderately large saline lakes and claypans in northern Simpson Desert.

Significance for Biodiversity Conservation: (Regional) An unusual wetland type in the SSD bioregion. Possible values for wetland birds.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Snake Creek Interdune Floodout Lakes

General Description: An area of intermittently flooded and exceptionally deep freshwater lakes and swamps between tall sand dunes of the Simpson Desert. Inundation is from the Finke River, along one of two main channels that exit the area generally referred to as the Finke Floodout (or Finke Floodout Forest).

Significance for Biodiversity Conservation: (National/International) A large area of very and relatively long-lasting temporary freshwater lakes, some of which are unusually deep, supporting significant populations of wetland birds.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, ?3

Ramsar Criteria for International Significance: 1, 3, ?5

15.10 Stony Plains Bioregion

Physiography

Only a small portion of the Stony Plains Bioregion occurs in the NT but it contains the highly distinctive Finke River Floodout Forest. The NT part of the Stony Plains Bioregion has areas of stony plains and uplands that force the Finke River east where the main river channel disappears as it floods out and is joined by its last significant tributary, Coglin Creek (also known as Charlotte Waters). The NT portion of the Stony Plains also includes areas of dunes with various inter-dune swamps and claypans, however these parts would probably be better placed in the Finke or Simpson-Strzelecki Dunefields bioregions.

Summary of Wetlands

The Inland Crab (*Holthusiana transversa*) is known from the Charlotte Waters area. A possible new taxon of *Cyperaceae* was collected on Wall Creek. There is a waterhole of poorly known values on the north side of Mt Wilyunpa, but is presumed to be the largest and longest lasting in the floodout forest.

Table 49. Preliminary table of wetland types in the Stony Plains Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1221	Small Freshwater Lakes and Pans	✓
B2211	Wooded Swamps (Non-linear)	✓
B2212	Wooded Swamps (Linear/Riverine)	✓
B2221	Bluebush Swamps	✓
B2222	Lignum Swamps	✓
B2231	Grassy Freshwater Swamps	✓
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F0002	Wooded Flood-prone Flat	✓
Watercourses		
WU2201	Generally Dry (Temporary) Upland Channels	✓
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓
WL2005	Unwooded Lowland Watercourses	?
Artificial		
A1001	Dams Across Watercourses	✓

Important Wetlands

Duffield Swamp

General Description: A large Northern Bluebush swamp. The catchment is adjacent gibber plains and low hills.

Significance for Biodiversity Conservation: (Regional) Good wetland bird habitat. Not thoroughly searched and may harbour populations of rare plants such as *Eleocharis papillosa*.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Skull Creek Swamps (New Crown)

General Description: A series of small swamps and pans associated with Skull Creek. Some of the swamps are confined by low sand dunes. Vegetation structure varied, including open Lignum, Cotton Bush and forbs and low sedges.

Significance for Biodiversity Conservation: (Regional) A good example of a series of small swamps.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Finke Floodout Forest

General Description: An extensive area of densely wooded/forested floodout of the Finke River

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: 1

15.11 Tanami Bioregion

Physiography

The Tanami Bioregion is the largest in the NT, even after the separation of the Davenport Murchison Ranges as a separate bioregion at IBRA 5. It draws its name from the Tanami Desert in the north west of the arid NT, but extends further east than the area generally regarded as the Tanami Desert. Also, both the Tanami Desert and the Tanami Bioregion extend to the north of the arid NT wetlands study area (20° latitude).

The Tanami bioregion is characterised by large sand plains and low calcrete rises, large areas of sand dunes and occasional low rocky ranges. It includes the large floodout system of the Lander River, including Lake Surprise, and also the Hanson River which has a relatively minor floodout system. The main dunefields of the bioregion are associated with these two rivers but minor dunefields are scattered elsewhere (Gibson 1996). In the north-east of the study area is an aggregation of saline and semi-saline swamps, salt lakes, minor channels and drainage depressions; to the south and south west of Rabbit Flat. The northern part of the bioregion is very remote but includes numerous small swamps and claypans. Some of the saline lake systems are linked by highly saline minor channels which are sometimes erroneously referred to as paleodrainage channels. These surface channels may correspond to actual paleodrainages which are subsurface features.

The ranges that generate the head waters of the Lander and Hanson rivers include some of substantial elevation. These may have an orographic effect on rainfall, influencing the frequency of stream flows. The Lander River has a number of long-lasting waterholes, including in the lower reaches (e.g. Boomerang and Curlew waterholes). These are assumed to be temporary (dry more than 50% of the time) but more work is required to confirm this.

The landforms and biota of the Tanami Desert portion of the Tanami bioregion are broadly described by Gibson (1986).

Summary of Wetlands

Table 50. Preliminary table of wetland types in the Tanami Bioregion

Arid NT Code	Arid NT Wetland Type / Broad Type	Occurrence
Basins		
B1111	Highly Saline Lakes (Salt Lakes)	✓✓
B1121	Saline Lakes / Samphire Swamps	✓✓
B1211	Large Freshwater Lakes and Pans	?
B1221	Small Freshwater Lakes and Pans	✓
B1222	Isolated Rock Holes	✓
B2111	Samphire Saline Swamps	?
B2112	Non-Samphire Chenopod Saline Swamps	?
B2121	Saline Grassy Swamp	?
B2211	Wooded Swamps (Non-linear)	✓✓
B2212	Wooded Swamps (Linear/Riverine)	✓
B2221	Bluebush Swamps	✓✓
B2223	Other Shrubby Freshwater Swamps	✓ (e.g. Elkedra R.)
B2231	Grassy Freshwater Swamps	✓?
B2232	Herbaceous Swamps (non-grassy)	✓
Flats		
F	undetermined Flood-prone Flat	✓
Watercourses		
WU2201	Generally Dry (Temporary) Upland Channels	✓

WL1123	Large Turbid Near-Seasonal Lowland Waterholes	✓ (e.g. lower Elkedra R.)
WL1202	Temporary (Generally Dry) Lowland Waterholes	✓
WL2001	Major Wooded Watercourses	✓
WL2002	Minor Lowland Wooded Watercourses	✓ (e.g. Elkedra R.)
WL2003	Melaleuca Dominated Lowland Watercourses	✓
WL2005	Unwooded Lowland Watercourses	✓
WL2007	Highly Saline Channels	✓
Springs		
	<i>Springs of unknown character</i>	✓ (e.g. Chilla Well area)
Artificial		
	various stock waters	✓
A3001	Sewage Ponds	?
A4001	Mining Tailings Ponds	✓

Important Wetlands

Ancient Swamp

General Description: An infrequently filled wooded swamp of *Eucalyptus victrix*.

Significance for Biodiversity Conservation: (Regional) Various wetland plants and birds recorded. May support moderately large bird populations.

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Elkedra River Floodout Swamps

General Description: A series of wooded swamps inundated by the Elkedra River

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 2, ?3

Ramsar Criteria for International Significance: not assessed

Lake Surprise (Yinapaka)

General Description: A large wooded swamp with some relatively open areas.

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1,2,3

Ramsar Criteria for International Significance: not assessed

Lander River Floodout Swamps and Waterholes

General Description: An extensive area of wooded floodout and braided channels.

Significance for Biodiversity Conservation: (National)

Directory of Important Wetlands in Australia (DIWA) Criteria: 1, 4, 5

Ramsar Criteria for International Significance: 2

Sanctuary Swamp

General Description: A large swamp with Northern Bluebush (*Chenopodium auricomum*) and Gumbarked Coolabah (*Eucalyptus victrix*)

Significance for Biodiversity Conservation: (Regional) birds & plants

Directory of Important Wetlands in Australia (DIWA) Criteria: 1

Ramsar Criteria for International Significance: not assessed

Warrabri Swamp - Skinner Creek Floodout

General Description: A floodout swamp.

Significance for Biodiversity Conservation: (Regional) not surveyed but probably holds water for substantial periods (based on comments from Bob Paul & Sean Leigh)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

Wycliffe Creek Floodouts

General Description: An aggregation of various wetland types associated with the floodplain and floodout of Wycliffe Creek

Significance for Biodiversity Conservation: (Regional)

Directory of Important Wetlands in Australia (DIWA) Criteria:1

Ramsar Criteria for International Significance: not assessed

15.12 Reservation Status of Wetland Types

The reservation status of the various wetland types has not been systematically determined. However, it is readily apparent that some types are not well represented in the reserve system or completely absent. The addition of Newhaven Station to the reserve network will go some way to address this; particularly for saline lakes and swamps. Currently the land tenure of Newhaven is still pastoral lease. There is no major wooded swamp (non-linear) or bluebush swamp in the current reserve network.

15.13 Comparison With Wetlands of Neighbouring States

Scope

Some features of arid NT wetlands are distinctive with the Australian arid zone while others are common to other parts of the arid zone. The main examples of each case are discussed here. Wetlands listed in *A Directory of Important Wetlands in Australia* (Environment Australia 2001) from areas adjacent to the arid NT are compared to arid NT wetlands.

General Comparison

Comparisons between wetlands of the arid NT and interstate areas of the arid zone are limited by the lack of equivalent published inventories for the neighbouring areas. Nevertheless, some important differences are clear.

Most of the major rivers of the arid NT rise within the arid zone and drain internally. In South Australia, several major rivers drain internally from within the arid zone, but have significantly less elevated catchments than those rising in the MacDonnell Ranges and are also different in that their surface waters may be joined at Lake Eyre. The rivers of the Pilbara Region in Western Australia rise in the arid zone but flow to the sea. The main arid zone rivers of Queensland, New South Wales and north-eastern South Australia all have their main catchments in the wet-dry tropics or in the east coast highlands ('Great Dividing Range').

The 'Finke Flood Out Forest' and the 'Snake Creek Interdune Lakes' have no known equivalent interstate.

The large Coolabah Wooded Swamps, associated with the floodouts to the north of the tropic of Capricorn are distinctive and may not have interstate equivalents.

The saline lakes of the Central Australia Discharge Zone form one of the longest playa chains in Australia. They are hydrologically distinct from the large salt lakes of South Australia. Those in the Curtin Springs area may be the most highly saline lakes in Australia.

Lake Mackay is one of Australia's most isolated large salt lakes. It is most significant for the proven breeding of Banded Stilts combined with remoteness from 'artificial' breeding sites for their predator, the Silver Gull. In other ways the lake may be similar to other salt lakes in Western Australia and South Australia, yet it may also have other distinctive features yet to be discovered.

Lake Lewis is distinctive in that it has a relatively active series of surface channels, which can inundate it.

Salt Creek Lake is distinguished by the recent longevity of inundation, which exceeded two years.

The spring-fed relict streams of the MacDonnell Ranges Bioregion are distinctive for their aquatic invertebrate fauna and a distinctive flora, which includes endemic and relict plants. Other spring-fed wetlands in the MacDonnell Ranges Bioregion also support endemic plants and animals in a variety of wetlands including large riverine pools, small pools in gorges and shaded seepage areas in gorges. The three endemic fish species of the Finke River reflect its geographic isolation from other river systems with diverse fish assemblages.

All these factors make the MacDonnell Ranges Bioregion a unique centre for biodiversity and endemism in wetlands.

Some arid NT wetland types and characteristics are common in other parts of the arid zone, including Bluebush swamps, claypans, various types of temporary watercourses, and saline swamps and lakes (despite some unique characteristics as listed above).

Some wetland types that are important in interstate arid areas have only minor occurrence in the arid NT or are totally absent. Large spring systems associated within the Great Artesian Basin are not known in the NT. Large braided floodplains are not known but form vast wetlands to the east and south-east in Queensland. Large expanses of Lignum swamp are rare or absent in the NT, although Lignum is a common element of some riverine and basin swamps.

Comparison With Wetlands in Adjacent Parts of Neighbouring States

A Directory of Important Wetlands in Australia (Environment Australia 2001) provides a useful summary of important wetlands in areas of central Australia that neighbour the arid NT. However, it should be born in mind that Directory listings do not include all wetland types of particular geographic areas. The following list presents information from the Directory, indexed by the reference numbers established at the third edition and with the IBRA bioregion code in brackets. A brief description is given for those that are within 100km of the arid NT with a comparison to arid NT wetlands. The online Directory may be consulted for full descriptions of these sites.

There are several springs, rockholes and seepage areas in the Musgrave and Mann Ranges, just over the South Australian border and some may be permanent. None is listed in the Directory.

Sites Within 100 km of NT

WA014 Rock Pools of the Walter James Range (CR) Two large, permanent rock pools, c. 9m across, in creek lines at the base of sandstone ranges. There are similar rock pools in the NT portions of the Central Ranges and Great Sandy Desert Ranges of unknown permanence. A relatively large number of permanent and long lasting rockholes occur in the MacDonnell Ranges bioregion. The WA014 rock pools have *Acacia cyperophylla* in the associated rocky creek. The nearest NT occurrence is in the Mount Wilyunpa area, in the far south of andado Station, with no associated permanent rock pools.

SA067 Dalhousie Springs (SSD) An aggregation of thermal springs of the Great Artesian basin, with no equivalent in arid NT.

QLD042 Toko Gorge and Waterhole (CHC) Spring and waterhole in low range system with a related, similar but probably smaller site at Nora Waterhole, up stream in the NT.

QLD117 Austral Limestone Aggregation (CHC) A large area of *Chenopodium auricomum* swamps associated with impeded drainage lines on a slightly elevated Tertiary limestone surface. There is no known equivalent in the arid NT.

QLD035 Lake Phillipi (CHC) A large playa (pan; c. 20 by 18 km) intermittently inundated with fresh water; predominantly bare with areas of *Eragrostis australasica* and *Muehlenbeckia florulenta* and some fringing Coolabah trees (*Eucalyptus sp.*). The lake is surrounded by a vast flood plain. Many similar but smaller pans occur in the NT but are not associated with vast floodplains.

QLD036 Lake Torquinie Area (CHC) Playa lakes, swamps and saline waterholes, on and adjacent to the Mulligan river, including permanent waterholes. There are wetlands in the arid NT with similar vegetation components but not of the same scale and arrangement.

QLD039 Mulligan River – Wheeler Creek Junction (CHC) Channels, playa lakes, claypans and swamps associated with the river junction, including some large permanent waterholes. There are wetlands in the arid NT with similar vegetation components but not of the same scale and arrangement.

QLD040 Muncoonie Lakes Area (CHC) A vast floodplain with anastomosing channels plus swamps, permanent waterholes and claypans. There is no equivalent in the arid NT.

Selected Arid Zone Sites Beyond 100 km of NT

- QLD023 Birdsville - Durrie Waterholes Aggregation (CHC)
- QLD028 Diamantina Lakes Area (CHC)
- QLD029 Diamantina Overflow Swamp – Durrie Station (CHC)
- QLD030 Georgina River – King Creek Floodout (CHC)
- QLD032 Lake Constance (CHC)
- QLD033 Lake Cuddapan (CHC)
- QLD034 Lake Mipia Area (CHC)
- QLD037 Lake Yamma Yamma (CHC)
- QLD038 Moonda Lake – Shallow Lake Aggregation (CHC)
- QLD106 Lignum Swamp (GUP)
- QLD118 Elizabeth Springs (MGD)
- QLD120 Lake Julius (MII)
- QLD121 Lake Moondarra (MII)
- SA001 Coongie Lakes (CHC)
- SA002 Diamantina River Wetland System (CHC)
- SA003 Strzelecki Creek Wetland System (CHC)
- SA066 Lake Eyre (SSD)
- SA068 Lake Eyre Mound Springs (STP)
- WA032 Lake Carnegie System (GAS)
- WA033 Windich Springs (GAS)
- WA038 Gibson Desert Gnamma Holes (GD)
- WA039 Lake Gruszka (GD)
- WA041 Lake Dora (Rudall River) System (GSD)
- WA043 Rock Pools of the Braeden Hills (GSD)
- WA044 Yeo Lake/Lake Throssell (GVD)
- WA052 Lake Disappointment (Savory Creek) System (LSD and GAS)
- WA053 Pools of the Durba Hills (LSD)
- WA067 Karijini (Hamersley Range) Gorges (PIL)
- WA069 Millstream Pools (PIL)
- WA096 Lake Gregory System (TAN)



16. Threats and Management Issues

Context and Scope

Unfortunately, many wetlands around the world have been destroyed or highly modified by various threatening processes. Threats include water extraction, draining for agriculture, urban and industrial development, pollution, invasive species of introduced plants and animals with a resultant loss of their beneficial functions and biodiversity (as listed in various publications; e.g. Environment Australia 1997).

In this section we discuss NT legislation that affects wetlands plus the main existing and potential threats: weeds, earthworks, water extraction; mining; feral animals; recreation, pollution, fire and explosives.

Unlike many other parts of Australia and the world, water extraction and river regulation are probably not significant threats to arid NT wetlands.

16.1 Legislation

Various pieces of NT legislation and several NT Government departments influence wetland conservation and management. The main ones are:

- the Parks and Wildlife Act;
- the Fisheries Act;
- the Weeds Act;
- the Pastoral Lands Act; and
- the Water Act.

Water resource management is controlled by the Water Act 1992 and an undated public document *NT Water* provides a 'detailed strategic framework for management' (p.1). Another undated NT Government document *NT Water, Blue Print for Future Direction* recognises the importance of environmental water quality but does not specifically address issues of environmental flows for wetlands and biodiversity conservation. The Water Act defines waterways and establishes controls over the use of water, obstruction of, interference with and pollution of waterways. Any construction activity to dam a waterway must be authorised under the Act. The Act does not control the creation of water storage structures that are not in waterways or the draining of land, so long as 'flow or likely flow of water in or into a waterway is not materially diminished or increased thereby' (section 40).

An inter-departmental memorandum sets out an agreement between the Parks and Wildlife Commission of the Northern Territory and the Fisheries Branch for joint responsibilities regarding inland aquatic environments.

16.2 Weeds

The spread of introduced plant species is deemed by this study to be the most significant threat to wetlands of the arid NT. This is consistent with Finlayson *et al.* (1988) who stated that weeds are the greatest threat to wetlands in the Top End. Under the Northern Territory Weeds Management Act 2001, noxious weeds are classed as:

- Class A Weeds - to be eradicated;

- Class B Weeds - growth and spread to be controlled; or
- Class C Weeds - not to be introduced to the Territory (also applying to all Class A and Class B Weeds).

Weeds that are known from arid NT wetlands, or likely to occur, are listed in table 51. The list includes species that have a high fidelity to wetlands as well as others that are more widespread in the landscape.

There are several introduced species which are threatening conservation values but are not listed as noxious. Listing them under the act is of great importance if their spread is to be curtailed and coordinated controlled programs developed.

Table 51. Weed species of arid NT wetlands.

Scientific Name	Common Name(s)	Class	Num Sites
Declared Noxious Weeds			
<i>Acanthospermum hispidum</i>	Starburr, Goats Head	B	2
<i>Argemone ochroleuca</i> subsp. <i>Ochroleuca</i>	Mexican Poppy	B	1
<i>Calotropis procera</i>	Rubber Bush, Rubber Tree, Calotrope, Kings Crown	B	0
<i>Cenchrus echinatus</i>	Mossman River Grass, Burr-grass	B	2
<i>Parkinsonia aculeate</i>	Parkinsonia, Jerusalem Thorn	B	11
<i>Prosopis pallida</i>	Mesquite, Algaroba	B	1
<i>Ricinus communis</i>	Castor Oil Plant	B	4
<i>Senna occidentalis</i>	Coffee Senna, Sickle Pod	B	2
<i>Tamarix aphylla</i>	Athel Tree, Athel Pine	B	6
<i>Xanthium strumarium</i> s.lat.	Noogoora Burr	B	14
<i>Tribulus terrestris</i> s.lat. (introduced & native forms occur)	Cat-head, Caltrop, Bindieye	B	
Other Weeds of Wetlands			
<i>Acetosa vesicaria</i>	Rosy Dock, Wild Hops, Ruby Dock		2
<i>Arundo donax</i> var. <i>Donax</i>	Giant Reed, False Bamboo		0
<i>Aster subulatus</i>	Bushy Starwort, Aster-weed, Wild Aster		1
<i>Bidens bipinnata</i>	Cobblers Pegs, Beggars Ticks		3
<i>Brassica tournefortii</i>	Wild Turnip, Turnip Weed, Mediterranean Turnip		22
<i>Carrichtera annua</i>	Wards Weed		1
<i>Cenchrus biflorus</i>	Gallons Curse		3
<i>Cenchrus ciliaris</i>	Buffel Grass		69
<i>Chloris inflata</i>	Purple-top Chloris, Purple-top Rhodes Grass		0
<i>Chloris virgata</i>	Feathertop Rhodes Grass, Furry Grass, Feather Finger-grass		7
<i>Citrullus colocynthis</i>	Colocynth, Bitter Paddy Melon, Colocynth Melon		17
<i>Citrullus lanatus</i>	Paddy Melon, Pie Melon, Wild Melon, Camel Melon		5
<i>Conyza bonariensis</i>	Tall Fleabane, Flax-leaf Fleabane		9
<i>Conyza bonariensis</i>	Tall Fleabane, Flax-leaf Fleabane		0
<i>Corchorus trilocularis</i>			1
<i>Crotalaria incana</i>	Woolly Rattlepod		1
<i>Cucumis myriocarpus</i>	Prickly Paddy Melon, Gooseberry Cucumber		2
<i>Cynodon dactylon</i>	Couch Grass		36
<i>Cyperus involucratus</i>			0
<i>Dichanthium annulatum</i>	Sheda Grass		4
<i>Digitaria ciliaris</i>	Summer Grass		2
<i>Echinochloa colona</i>	Awnless Barnyard Grass, Swamp Grass, River Grass		10
<i>Eragrostis barrelieri</i>	Pitted Lovegrass		3
<i>Eragrostis cilianensis</i>	Stinkgrass		0
<i>Gomphrena celosioides</i>	Gomphrena Weed		1
<i>Helianthus annuus</i>	Sunflower		0
<i>Heteropogon contortus</i> †	Bunch Speargrass, Black Speargrass		5
<i>Hyptis suaveolens</i>	Hyptis, Mint Weed		0
<i>Juncus acutus</i> subsp. <i>Acutus</i>	Sharp Rush, Spiny Rush		0
<i>Juncus bufonius</i>	Toad Rush		0
<i>Lactuca serriola</i>	Prickly Lettuce		5

<i>Leptochloa fusca</i> subsp. <i>Uninervia</i>	Beetle Grass		0
<i>Malva parviflora</i>	Small-flower Mallow		2
<i>Malvastrum americanum</i>	Malvastrum, Spiked Malvastrum		85
<i>Melia azedarach</i>	White Cedar		0
<i>Melinis repens</i>	Natal Red Top, Red Natal Grass		2
<i>Nicotiana glauca</i>	Tree Tobacco		4
<i>Pennisetum pedicellatum</i>			0
<i>Phoenix dactylifera</i>	Date Palm		1
<i>Polypogon monspeliensis</i>	Annual Beardgrass		1
<i>Rumex crispus</i>	Curled Dock		0
<i>Sida cordifolia</i>	Flannel Weed		0
<i>Sida spinosa</i> †	Spiny Sida		18
<i>Sisymbrium erysimoides</i>	Smooth Mustard		4
<i>Solanum nigrum</i>	Black Nightshade, Black-berry Nightshade		15
<i>Sonchus asper</i>	Rough Sow-thistle, Prickly Sow-thistle		1
<i>Sonchus oleraceus</i>	Milk Thistle, Common Sow-thistle		22
<i>Sorghum bicolor</i>	Forage Sorghum, Grain Sorghum, Cultivated Sorghum		1
<i>Stylosanthes hamata</i>	Verano Stylo, Verano, Carribbean Stylo, Stylo		0
<i>Tridax procumbens</i>	Tridax Daisy		0
<i>Urochloa mosambicensis</i>	Sabi Grass		0
<i>Verbena supine</i>	Trailing Verbena		0
<i>Xanthium spinosum</i>	Bathurst Burr		0

† native to arid NT but possibly introduced in some bioregions.

Additional information is presented below for the species of most concern, in approximate order of importance. This includes a summary of their distribution, abundance and invasiveness. The order of importance is based on a subjective assessment of the current and potential impact. Additional information is also included for some other species of less (or uncertain) concern.

Further analysis of the distribution of weed species is required including creating maps from distribution records. Further documentation of the degree of threat posed by each species will involve assessing the degree to which native species are being replaced and consequential changes to the ecological function of effected wetlands.

The first two species described below are of greatest concern: Couch Grass and Buffel Grass.

***Cynodon dactylon* (Couch Grass)**

Cynodon dactylon (Couch, Lawn Couch, Bermuda Grass) is the single worst threat to the flora of arid wetlands. *Cynodon dactylon* is widespread in most rivers including some relatively remote tributaries. It is also starting to encroach on various swamps. In rivers it often forms a virtual monoculture on steep and elevated banks. It has extremely deep reaching and persistent rhizomatous roots from which it can resprout.

The endangered sedge *Eleocharis papillosa* has apparently been displaced by Couch at Illparpa Swamp on the edge of Alice Springs and Couch is dramatically spreading at Stirling Swamp, another key locality for *E. papillosa*. Couch Grass, together with *Cenchrus ciliaris* (Buffel Grass) is displacing a variety of species along river margins, where both weeds are extremely widespread and abundant. This may be causing a widespread decline in *Cyperus bulbosus* (Nut Grass) which is an important food source for the Bilby, an endangered marsupial (P.Latz pers. comm. based on unpublished data from thirty years of monitoring at Simpsons Gap National Park). These introduced grasses dramatically alter fire regimes by allowing more intense and frequent fires in riverine environments.

The description of the Toko Gorge and Waterhole wetland (Blackman & Craven 1996) in *A Directory of Important Wetlands in Australia* (2nd edition p.232) lists *Cynodon dactylon* under notable flora, stating: 'Relatively undisturbed couchunderstory are uncommon in Queensland'. That account should be revised since the couch grass is probably threatening other values at the site..

Couch Grass is still actively planted and is very common as a lawn grass around dwellings and is probably also planted to stabilise soil in the vicinity of bores and to stabilise earthworks such as dams. It may also spread as seed or vegetatively via vehicles and possibly by waterbirds.

Cenchrus ciliaris (Buffel Grass)

Cenchrus ciliaris (Buffel Grass) is extremely widespread as a result of planting for dust control, revegetation projects and pasture improvement. It is now the dominant understorey plant in many rivers and is present in most riverine systems. It is also present in some swamps and in the vegetated fringe of claypans. *Cenchrus ciliaris* is probably still expanding in range and abundance in these environments. It is a highly competitive species that has a significant impact on biodiversity (Albrecht *et al.* Unpublished data). In rivers it is responsible for a drastic alteration to fire regimes due to its ability to produce a high biomass. It has apparently displaced Yalka (*Cyperus bulbosus*) an important traditional aboriginal food and food source for native animals such as the Bilby (*Macrotis lagotis*) (P.Latz pers. comm.).

Tamarix aphylla (Athel Tree, Athel Pine)

Athel Pine (*Tamarix aphylla*) is one of the major weeds of riverine environments in arid Australia. In the past it was very widely planted as a shade tree and is a typical part of many outback homesteads. In the arid NT it has a vast wild population in the Finke River system, having established down-stream of shade trees at Hermannsburg and Glen Helen, following a major river flow in 1974 (Griffin *et al.* 1989). A minor outbreak in the Ross River was controlled in the 1990's.

There are several factors that explain the outbreak of Athel Pine in 1975 despite many previous flow events which did indicate an outbreak. The 1974 flood is estimated to be the largest in 850 years in the upper Finke (Pickup 1991). It was large enough to carry Athel Pine debris from which new trees could establish vegetatively. This was combined with the removal of many River Red Gums by flood waters. However, the key factor may have been highly elevated discharge of saline groundwater flushed out of the Karinga Creek Paleodrainage system (Griffin *et al.* 1989). The following period of high salinity inhibited regeneration of River Red Gums and favoured the salt-tolerant Athel Pine. Continuing expansion of Athel Pine was favoured by the salt-laden leaf litter which it produces.

A second species of Tamarix (*T. ramosissima*) has also been planted as a shade tree in the arid NT, including on the floodplain of the Todd River in Alice Springs and at Finke Community adjacent to the lower Finke River. Although this species has not established wild populations in the NT, it is a major riverine weed in the south-west of the United States of America (M.Fuller *in litt.*).

In the Finke River, the infestation of Athel Pine occurs across the broad open sandy bed of the river, over 1km wide in parts, but also extends into the dense fringing Coolabah woodlands, which are impenetrable to vehicles in many areas, severely hampering monitoring and control activities (observations from this survey). The infestation has now reached the Finke Floodout Forest, (J.Gavin pers. comm.); an area of very dense Coolabah (*Eucalyptus coolabah subsp. arida*) and Cooba (*Acacia salicina*) woodland/forest.

Until recently, the wild population of Athel Pine was virtually restricted to the Finke River below Glen Helen Gorge. Following heavy rains in 2000 and 2001 it has infested Karinga Creek and associated semi-saline lakes (first recorded during the wetlands inventory). It has also been recorded from some isolated claypans and part of the Lucy Creek catchment which is another tributary of the lower Finke. Possibly this is due to a combination of widespread seeding in the Finke River, wind dispersal of seed and unusually high and persistent soil moisture in the broader landscape.

A control program has been making inroads into the Finke River infestation over the past decade, run by landholders, through the Centralian Land Management Association, and in cooperation with the NT Government. A national strategy has been released for the control of Athel Pine, which includes more details of its distribution and impact (ARMCANZ 2001).

Xanthium strumarium s.lat. (Noogoora Burr)

Noogoora Burr (*Xanthium strumarium s.lat.*) has a strong preference for drainage lines and alluvial flats in the arid NT but also occurs on heavy clays of the 'black soil plains'. The burrs are easily transported by flood waters and contain two seeds of which one may remain dormant but viable for over a decade. It

forms large dense thickets which can virtually exclude other understorey plants and thus is a threat to the biodiversity of wetland plants.

There has been a persistent population in Trepkina Creek which has been monitored and controlled but not eradicated. There are infestations along Sixteen Mile Creek on the Burt Plain and in the interim floodout of the Todd River (near the Alice Springs Airport) (J.Gavin pers. comm.). There is an infestation in the lower floodout of Kurundi Creek which has been fenced off from stock (A. Clough pers. comm.). It is presently a typical component of riverine environments in all the parts of the Georgina system surveyed for the wetlands inventory and is abundant on parts of the Bunday River in the Sandover system. It seems inevitable that it will spread throughout the lower Sandover River and floodout. It is not recorded in the Dulcie Ranges, much of which is a catchment for the Sandover system. The Dulcies are botanically important and efforts should be made to keep them free of Noogoora Burr.

It has apparently been present in the tributaries of the Georgina River for several decades (R.Dance pers. comm.) but pastoralists report a rapid increase in abundance in the past two years.

The Finke River system includes areas of prime habitat for Noogoora Burr such as the Finke Floodout forest and the linear Coolabah swamps fringing long sections of the mid and lower reaches of the main river. At present there are no records of Noogoora Burr in the catchment.

A coordinated response between landholders is essential if this species is to be controlled and will require a long-term commitment of resources.

There are established infestations of the related species Bathurst Burr (*Xanthium spinosum*) in the arid NT. Infestations in the upper catchment of the Hugh River in the Finke River system have been mapped by PWCNT rangers and some control work undertaken (Chris Day pers. comm.). The infestation may have been present for over a decade but has probably expanded during the wet years of 2000 and 2001 (C. Schmidt pers. comm.). Relatively little is known about the habitat preferences of this species in the arid NT. In higher rainfall regions it is a weed of pasture and cropping lands but may have a stronger preference for wetlands in the arid zone. In the upper Hugh River area it occurs in watercourses, including the Hugh River, but is not restricted to them. The main areas of the infestation are not currently in the drainage lines. There is a strong possibility that seeds have spread into the mid-lower reaches of the Finke River, via the Hugh.

***Malvastrum americanum* (Malvastrum, Spiked Malvastrum)**

Malvastrum is a very widespread and common weed in wetlands including river banks, swamps and flood prone flats. It occasionally forms dense stands.

***Parkinsonia aculeata* (Parkinsonia, Jerusalem Thorn)**

Parkinsonia is moderately widespread in latitudes to the north of the Tropic of Capricorn. Several new locations were recorded during the wetlands survey and forwarded to the NT Government Weeds Branch. Only one dense thicket was encountered but it is known to have the capacity to form extensive dense thickets. In 2001 the Lake Eyre basin Coordinating Group gained \$295,000 for controlling *Parkinsonia aculeata* in the Lake Eyre Basin (Newsletter of the Lake Eyre Coordinating Group, Issue 19). The funding is from the Natural Heritage Trust through Agriculture, Forestry and Fisheries Australia (Commonwealth Government) and is part of the National Parkinsonia Program.

***Argemone ochroleuca* subsp. *ochroleuca* (Mexican Poppy)**

Mexican Poppy is a major weed of the Finke and Todd river systems. In our survey it was also recorded at an isolated wooded swamp in the Mitchell Grass Downs bioregion, where it was extremely abundant.

Dichanthium annulatum (Sheda Grass)

Sheda Grass is not widespread in the arid NT but is considered highly invasive. There are infestations at Illparpa Swamp and various other locations around Alice Springs. In the inventory survey it was recorded at two sites. One was a large grassy swamp in the Georgina River system (Channel Country bioregion) on the north side of the Toko Range, where it was one of two dominant grasses. The other site was Running Waters on the Finke River. The presence of Sheda Grass in the Finke River is of particular concern as it may compete aggressively with *Eriachne benthamii s. lat.*, which dominates some grassy swamps in the mid to lower sections of the Finke system.

Juncus species (rushes)

Toad Rush (*Juncus bufonius*) was first recorded in 1983 at Ross River Homestead (tourist lodge) in the Ross River. It has been recorded at Illparpa swamp. Of greater concern is Spiny Rush (*Juncus acutus subsp. acutus*). Spiny Rush is displacing the native *Juncus kraussii* in some areas of coastal Australia (Adam 1994) and is present in the arid NT. It was first recorded here in 1996, from the Finke River, downstream of Ormiston Gorge. Despite control efforts, it has now spread downstream as far as Finke Gorge (D.Albrecht observations 2001).

Melinis repens (Natal Red Top, Red Natal Grass)

Red Natal Grass is moderately widespread and abundant in riverine habitats.

Cenchrus echinatus (Mossman River Grass, Burr-grass)

Mossman River Grass is far less widespread than the closely related Buffel Grass but is a declared noxious weed due to the burrs. It appears to favour moist areas such as creek lines and was observed at various locations in addition to formal survey sites. A major infestation has been reported at the creek below Muranji Rockhole (P. Laughton pers. comm.).

Brassica tournefortii (Wild Turnip, Turnip Weed, Mediterranean Turnip)

Turnip Weed is a very widespread and common weed that occurs in both wetlands and drylands. Wetland types in which it is common include river banks, linear wooded swamps and other swamps and flood prone flats. It occasionally forms moderately dense patches.

Ricinus communis (Castor Oil Plant)

Castor Oil Plant is common along the mid to lower Finke River, where it can form dense clumps, but appears to be controlled by pathogens or insects (H. Murphy pers. comm.) including caterpillars (P.Latz pers. comm.). It is recorded from Chrissie Creek in the Petermann Ranges.

Assorted Observations on Other Weed Species

Annual Beardgrass (*Polypogon monspeliensis*) is abundant at Illparpa Swamp but was only recorded at one survey site (Running Waters). It has also been recently recorded in the Musgrave Ranges of northern South Australia (A. Duguid, obs. 2002), where it was common along a rocky upland creek with flowing spring water. This species may become a serious weed of long-term swamps and could potentially compete with rare wetland plants such as *Eleocharis papillosa* and *Imperata cylindrica*.

Tree Tobacco (*Nicotiana glauca*) was abundant and conspicuous at sites on the mid and lower Finke River during the wetlands survey. It was also present in the floodout forest. However, it did not form dense stands and was not obviously competing with natives.

16.3 Water Retention Earthworks

Numerous instances of excavated tanks or 'dams' were encountered where holes have been excavated by landholders to create a relatively deep water storage for stock, in which water withstands the losses of evaporation far longer than in the surrounding wetland. These are frequently called dams, however they do not block the flow of water and in general, do not greatly change the flow or distribution of surface waters. Such structures were encountered in claypans and swamps. The main impact is on the wetland vegetation, due to increased grazing and trampling that occurs by domestic stock in the vicinity of watering points.

Only one instance was encountered in which a large wetland had been deliberately drained, being a claypan that was blocking an access track when inundated. The enlargement of existing wetlands by trapping water behind dams or levee banks was, in contrast, relatively common. It is not possible to tell from this broad inventory whether these type of earthworks have caused a net gain or loss for wetland biota.

Waterbirds have undoubtedly been advantaged by the great increase in long-term and permanent waters resulting from various types of stock dams. Some of the true aquatic plants are relatively common in artificial waters in the study area. The picture for predominantly ephemeral swamp plants is less clear. In some places, levee banks that channel water to dams across relatively flat terrain, have created or increased wetland areas. Indeed, such earth works are frequently done in areas prone to some natural inundation. Dams across more clearly defined creek lines generally have limited effect on existing swamps and neither do they generally create much swamp habitat. There is no recorded instance of such structures acting as a barrier to upstream movement of fish in the study area. It is likely that the permanent and semi-permanent dams created by the cattle industry have allowed the survival of fish in river systems in to which they have been introduced.

Artificial waterbodies can be a focal point for feral horses and as a result may have an adverse effect on conservation values of the surrounding drylands. A small number of instances were encountered where springs or seepage areas have either been dammed or inundated by water from damming a watercourse.

A major flood mitigation dam was proposed for the Todd River up stream of Alice Springs, with preliminary construction work taking place in 1992. Work was suspended for 25 years by order of the Commonwealth Minister for Aboriginal affairs. The dam would have significantly altered flow regimes with an unknown impact on the downstream ecology. Earlier proposals for a recreation dam for the town of Alice Springs were investigated (e.g. *Alice Springs Recreational Dam – Preliminary Water Quality Investigation* 1979) but have not been carried through.

There was also once a proposal to build a recreational lake on the Hugh River (R. Read pers. comm.) and another proposal for Ilparpa Swamp (P. Latz pers. comm.).

16.4 Water Extraction

Water extraction for commercial horticulture, domestic use, mining and for stock is predominately from ground water. There are no documented effects on surface waters in swamps or waterholes, however, the possibility exists in some areas. Impacts may be hard to detect due to the high natural variation in the water regime of arid NT wetlands and the lack of baseline information prior to the commencement of extraction.

Ground water extraction for horticulture is increasing. The impacts on wetlands are unquantified but are considered to be minimal. Stirling swamp is described here as an example. The swamp is a discharge zone for the Ti Tree ground water basin. Although substantial volumes of ground water are extracted for horticulture, the volume is small compared to the large volume that is likely to be discharging through soil and vegetation at the swamp (P. Cook pers.comm.).

16.5 Mining

Mining can have direct and indirect impacts on wetlands. Direct impacts include excavation in a wetland. Potential indirect impacts include pollution and adverse changes to ground water. One example of Gypsum extraction from the bed of a salt lake was encountered during the survey and investigations have been conducted into the viability of extracting minerals from salt lakes in the area (B. Kilgarif pers. comm.). Jacobson (1996) reports that mineral exploration leases have been issued for various parts of the Central Australian Groundwater Discharge Zone (the chain of playas that includes Lake Amadeus and the Karinga Creek Lakes) for the mineral content of the brines. The brines may also have commercial use as a medium for cultivating 'valuable algae (*Dunelliella*) and cyanobacteria (*Spirulina*)' (Jacobson 1996, p. 265).

One instance of surface gravel stripping is recorded for a large stony claypan (Lehman & Edgoose 1996).

An instance of indirect mining impact occurs at Lake Lewis where hypersaline water is disposed from a petroleum extraction operation. The impacts of this are being monitored by an environmental consultant.

16.6 Introduced Aquatic Animals and Translocations

There are several records of introduced fish and invertebrates in the arid NT and these are discussed in the overview of fish in chapter 10 and observation on aquatic invertebrates in chapter 11. It is feared that Mosquito Fish (*Gambusia spp.*) could gradually out compete native fish if they become established in river systems with fish populations. This is of particular concern for those drainages with endemic species: the Finke River and possibly the Frew River. The effect of introduced Yellowbelly (*Macquaria sp.*) on indigenous species in the drainages of the Davenport Ranges is unknown. The effects of introduced crustaceans such as Redclaw (*Cherax quadricarinatus*) and the Yabby (*Cherax destructor*) are also unknown, but Davis (1995) regards them as a serious threat. Since Yabbies in the Finke River system may pre-date the arrival of non-Aboriginal people it is possible that genetically distinct populations are being lost as they interbreed with escapees from stocked dams.

Introductions of fish and crustaceans to places that could overflow into natural river systems is quite possibly ongoing.

There is no commercial aquaculture business currently operating, however, there have been past attempts to establish commercial enterprises and there is current interest. These operations may bring a risk of the escape of fish, aquatic macro-invertebrates or pathogens, to native waterways.

Cane Toads (*Bufo marinus*) could potentially colonise the permanent waterholes in the northern part of the study area where frosts do not occur.

16.7 Exotic Terrestrial Animals

The effects of introduced predators on arid zone fauna in general are well documented. There is little or no specific data for wetland birds but there is undoubtedly some impact. The impacts of introduced herbivores, both domestic and feral, are hotly debated, yet there remains a lack of good data to make assessments. Observations in this study were not made in such a way as to enable quantitative assessment of the impact of stock on wetlands and it would be impossible to do so with rapid one off visits. Nevertheless, fresh water wetlands of virtually all types are focal points for domestic stock, for water and often for feed as well, and there is inevitably a great deal of soil disturbance that would otherwise not occur. This may increase erosion rates and therefore potentially increase siltation of some wetlands, due to reduction in ground cover plants and physical disturbance of ground.

The Australian Society for Limnology includes grazing in a list of critical challenges for wetland conservation, in a policy document on its website (internet site for ASL: [asl_poldoc_challenges.htm](http://asl.poldoc_challenges.htm) 25/9/01). Impacts on plants occur by 'compacting, pugging and trampling, selective grazing and nutrient increases' (Brock 1997, p.132). Aquatic fauna may be adversely affected by increased turbidity and disturbance to fringing and emergent vegetation and by decreased longevity of the surface water when drinking by stock is added to evaporation. Bunn and Davies (2001, p.20) state that 'extensive and

repeated disturbance of the margins of waterholes by stock and feral animals could limit algal production and threaten the very food base of crustaceans, snails and fish’.

There is anecdotal evidence that some species, which are selectively grazed, can be removed altogether by heavy grazing. *Chenopodium auricomum* (Northern or Queensland Bluegrass) is an example.

Davis and Froend (1998) suggest there is evidence of nutrient enrichment from introduced herbivores: ‘The wetlands of central Australia, in particular the wetlands of the Finke River and the gorges and river pools within the West MacDonnell Ranges display varying degrees of nutrient enrichment due to pastoral activities within their catchments and their use by feral animals (e.g. horses, camels). [] Excessive growth of macrophytes such as *Myriophyllum* [] and *Typha*, is believed to be a consequence of nutrient enrichment arising from pastoral activities.’ (Davis & Froend 1998, p.5&6). However, Williams and Siebert (1963) discuss generally high nitrate levels in ground water of central Australia and the possibility that it is partly due to nitrogen fixation by *Acacia* species. In our survey we observed dense areas of *Myriophyllum* and patches of *Typha* in drainage lines in rocky hill country where there is little if any cattle grazing although probably some feral donkeys and horses.

Storrs and Finlayson (1997) briefly discuss the benefits of excluding stock so as to protect wetland and other biodiversity values. This included the possibility of fencing off permanent and near-permanent waterholes. However they note that excluding stock from wetlands could affect enterprise viability for some stations. They suggest a more radical proposal that as much as 10% of current cattle production areas in central Australia should be removed from grazing, with negotiated compensation. Regardless of financing of stock exclusion fencing, it is essential that such works be done with the full support of landholders in order that fences and appropriate stock management be maintained.

Beds of Water Reeds (*Phragmites australis*) are believed to have declined due to impacts from exotic grazing animal, for example at Running Waters (Latz 1982; PWCNT 1997a). However, substantial recovery is reported when grazing is stopped such as following feral horse control at Palm valley (D.Matthews pers. comm.).

In addition to trampling and grazing impacts, both stock and feral herbivores may negatively affect wetland plants and animals by drinking large quantities of water from small wetlands, resulting in reduced duration of inundation. Feral camels are widespread in the study area, including the remotest parts, and their impact may be significant, although hard to quantify.

16.8 Recreation

The permanent and long-term waterholes of the West MacDonnell Ranges and the George Gill Ranges are focal points for tourism and many are popular swimming spots. Sunscreen and insect repellent are potential threats to waterholes (Davis 1995 and Storrs & Finlayson 1997). Many of the permanent and semi-permanent waterholes that serve as a refuge for some species during droughts are also intensively used for commercial tourism. There is little quantified data on the impacts involved (e.g. Rippon *et al.* 1994 cited in Storrs & Finlayson 1997).

Recreational boating is known from at least three large saline lakes and two freshwater lakes that were inundated during this study. At least one is moderately intensively used for water skiing with possible loss of bird breeding opportunities due to frequent disturbance. Other potential but unquantifiable impacts include habitat modification and contamination of water by sunscreen and insecticide, fuel and oil. Recent reports on disturbance of waterbirds by human recreation activities in Australia may be useful in assessing impacts in arid NT (Paton *et al.* 2000; and Collins *et al.* 2000).

16.9 Pollution

Pollution from industrial or agricultural chemicals or from domestic effluent is undocumented in the area. Runoff from the streets of Alice Springs undoubtedly transports some pollutants to the Todd River. Defecation and urination of stock at intensively used waterholes is expected have some effect on water chemistry but is unquantified and the consequences for native plants and animals unknown. Nutrient enrichment of Illparpa Swamp has resulted from overflow of treated effluent water from the adjacent

Alice Springs Sewage Ponds. The degree to which the dramatic vegetation changes at the swamp are a result of changed water regime or changed nutrient status is unknown.

16.10 Fire

Fire can be a significant form of disturbance in wetlands. Woodland, shrubland and grassland components of wetlands can all burn in some circumstances. The rapid expansion of some introduced grasses in riverine wetlands has dramatically increased the biomass and continuity of ground fuel loads. As consequence bushfires can burn more intensely and frequently. There is some observational evidence that wetlands can be covered over by sand drifts following wildfires (Gibson *et al.* 1994).

16.11 Explosives

Several spring outlets have been blasted with explosives in an attempt to increase water flows for stock, however, not only does this impair the natural values, it sometimes has the effect of actually reducing surface flow (P. Latz pers. comm.).



17. Conclusions and Recommendations

17.1 Overall Value of Wetlands in Arid NT

The importance of most individual wetlands and of the combined suite of arid NT wetlands is poorly known, a situation only partly addressed by this broad inventory. Nevertheless, we have identified many wetlands as being of national and international importance for maintaining biodiversity. Wetlands in the arid NT sustain plant and animal species that are endemic to the region, as well as isolated and relictual populations of more widespread species. The wetlands also support important populations of nationally endemic species such as the Banded Stilt, which although vagrant is now confirmed as episodically breeding here in large numbers.

Although not quantified, the collective importance of a large number of small wetlands must not be overlooked. Many wetland species have naturally widespread and relatively sparse populations and rely on scattered small wetlands for their existence. Individual wetlands may therefore be important as components of aggregations across large distances, even where an individual is relatively small. Therefore, the wise use of individual wetlands may be very important to sustain regional biodiversity.

The main economic values of arid NT wetlands are for tourism and pastoralism. Many wetlands are of great significance in Aboriginal culture and spirituality.

Arid NT wetlands may provide an important resource for research into past climates and ecosystems, through pollen that is stored in sediments.

17.2 Condition of Wetlands in Arid NT

In the arid NT there has been relatively little wetland loss from land clearing or drainage and diversion works for agriculture. Those factors have caused massive reductions in wetland area and quality in some other parts of Australia.

However, there are few wetlands that have not been affected by feral grazing animals, domestic grazing stock or weeds. Of these three, weed invasion is considered to be the biggest threat to biodiversity values. The situation is not well quantified but there is clear evidence that few wetlands are weed free and that the most invasive species are rapidly spreading. Riverine environments are the worst affected at present, since the natural disturbance regime of episodic floods favours colonising species which includes most weeds. There is evidence that weeds are also encroaching swamps and claypans. Weed invasion is undoubtedly a threatening process for some wetland plants, which if left unabated may lead to extinctions.

17.3 Landholder Attitudes and Perceptions

Many landholders value the presence of wetland birds and possibly plants and other animals. In our survey we did not encounter any negative attitudes to wetlands. Perhaps due to the large size of properties, there is less concern about the effects of wetlands on access, agricultural production or mosquito breeding than in more densely populated parts of the country. The relatively positive attitudes may equate to receptiveness to conservation messages. However, we frequently encountered scepticism

about the use of the term 'wetland' for areas that are generally dry. Also, many pastoralists are defensive in regard to possible impacts from cattle. Several made statements to the effect that plants and animals that have survived many decades of grazing, or even over a century in some places, have shown that they are compatible with current land use.

17.4 Data Limitations

The large size of the study area compared to the time and resources available for this inventory, mean that there are various gaps in the spread of ground and aerial survey sites. Relatively little field work was done in the MacDonnell Ranges Bioregion because it was the best known area prior to the survey, both in the authors' general experience and in pre-existing documentation and research. The north western portion of the Tanami Bioregion was also under sampled. Previous survey work supplemented by strategic sites surveyed in this project was considered to provide an adequate basis for documenting the wetland values of that region. The Murchison Ranges and the area of the Tanami Desert to their west were not sampled. Most of the survey gaps are on Aboriginal Land and considerable time should be allowed for consultations in any plans for future survey. The central Simpson Desert in the region of the borders with South Australia and Queensland was not sampled due to its remoteness. The portion of the Great Sandy Desert to the south and south-east of Lake Mackay was not visited. Also, the far south west corner of the NT, to the south of the Petermann Ranges was not surveyed and is poorly known. Existing mapping and recent satellite imagery indicate that there are few large or longer lasting wetlands there.

17.5 Recommendations for Community Education

Educational and promotional material should be developed to increase understanding of arid NT wetlands and their importance. A one-page information sheet could be created for each wetland type, similar to those created for south-west Queensland by Jaensch (1999). An additional sheet or sheets could cover the general abundance, distribution and values of arid NT wetlands. The same information could also be presented on the internet. Other material should be produced for traditional Aboriginal landholders for whom English is often a second or third language.

An information campaign is recommended regarding the degree of threat posed to wetland values from the most invasive weed species, and should include ways to avoid spreading weeds.

An information campaign is also recommended about the risks associated with translocating or introducing fish and crustacean. People living in and near the catchments of high aquatic biodiversity should be targeted, such as: the Finke River, Frew River, Whistleduck Creek, the long-term waters of the George Gill Range (Kings Canyon/Watarrka area) and the Dulcie Ranges. This type of education applies equally to those undertaking deliberate introductions, to developers of commercial aquaculture and to owners of pet fish and invertebrates in aquaria.

There is scope for increased education of tourism providers of the need to limit or avoid sunscreens and insect repellants when bathing in waterholes.

Community education regarding wetland conservation should be guided by the general principles set out in the national action plan: the *Wetland Communication, Education and Public Awareness (CEPA) National Action Plan* (internet site of EA: cepa0105.html). Community education will be most effective when undertaken cooperatively. Accordingly, various interest groups should work together including Waterwatch, the NT fisheries authority, Parks and Wildlife and other components of the Department of Infrastructure Planning and Environment, and the Education Department.

17.6 Recommendations for Management

Law Enforcement

Legislated responsibility for protecting aquatic life and controlling its utilisation are mainly with the Fisheries Branch of the NT Government, however, all the Fisheries officers are based in the Top End. Consequently it is difficult for them to perform education and law enforcement duties in the arid NT,

some 1000 to 1700km from Darwin. It is recommended that some way be found to increase education and protection measures regarding aquatic life in the arid NT. The Parks and Wildlife Commission has some powers to protect aquatic life in conservation reserves by designating no-fishing areas.

Conservation Management

Further work is required to assess the level of any long-term impacts that human wetland use may be having, including cattle production. As this work will be a long-term activity, a precautionary approach should be applied such that representative wetlands or parts of wetlands should be managed for the conservation of biodiversity. This need not necessarily preclude all other land uses. However, fencing to control or exclude stock access to some wetlands, or parts of wetlands, will often give the best protection to natural values. The costs involved include fencing materials and construction and may also include the provision of artificial watering points for stock. Conservation works such as fencing may require the provision of funds or other assistance to landholders.

Priority should be given to formulating management plans for all important wetlands including plans for monitoring, further biological assessment, weed control, and management of grazing regimes. Some wetlands are already covered within park plans of management.

There is no doubt that some wetland areas are 'essential habitat' for some species. It is recommended that some such wetlands should be declared as essential habitats under the Territory Parks and Wildlife Act. Primarily this should be done for habitats that occupy a relatively small total area and where there are threats to their ability to support the dependent plants and animals.

Both cooperative and legislated approaches for off-park conservation of wetlands should be pursued. The protection of some important wetlands in new national parks should also be considered.

Management of weeds should involve the following:

- listing important environmental weeds as noxious, most critically *Cynodon dactylon* and *Cenchrus ciliaris*;
- a ban on the sale and sowing of *Cynodon dactylon*;
- raising awareness of the impacts of environmental weeds;
- creating better identification guides;
- more education on ways to avoid spreading weeds;
- increased resources to the government weeds branch;
- increased assistance and incentives to private landholders for weed control;
- monitoring encroachment in key areas, such as Stirling Swamp;
- a pilot study on the possibilities of reversing *Cynodon dactylon* (Couch Grass) encroachment on swamps;
- investigation of control options for introduced grasses in rivers, particularly *Cynodon dactylon* and *Cenchrus ciliaris*;
- continuation of the Athel Pine control program.

The waterholes surveyed in several catchments of the Dulcie Ranges, were free of Couch Grass (*Cynodon dactylon*) and Noogoora Burr (*Xanthium strumarium* s. lat.) and had a relatively low abundance of Buffel Grass (*Cenchrus ciliaris*). All three weed species are abundant lower in the Bunday-Sandover drainage system, while Couch and Buffel are abundant in the Plenty-Hay drainage system (the other major system for which the Dulcies provide catchment). It is recommended that management actions be taken to control access into the ranges by feral and domestic herbivores (mainly cattle and horses) which will otherwise eventually convey these weed species into the Dulcie Ranges. This will require further survey to establish 'clean' areas, fencing, and increased feral animal control. The majority of the land area is pastoral lease so a formal agreement to conduct such management would need to be negotiated and considerable funding made available.

Consideration should be given to the protection of good examples of each main wetland types. These would serve as important 'reference standards' for assessing impacts and changes in other wetlands. A number of wetlands in national parks serve in this way and some stock exclosures already exist on cattle

stations. To be most effective, reference areas would need to have major weed species controlled, be ungrazed by exotic species and have undisturbed hydrological function. However, most riverine systems are heavily infested with *Cenchrus ciliaris* and *Cynodon dactylon*, including those on national parks, and current weed control methods are only viable for very small areas for these species. Also, these species are generally regarded favourably by pastoralists as stock feed.

17.7 Recommendations for Further Inventory and Research

Overview

This reconnaissance inventory has laid a solid foundation for future, more detailed inventory of wetlands in the arid NT. Future inventory is required as a basis for conserving the biodiversity of the region's wetlands, and should include the following general tasks:

- further consultation with landholders regarding their knowledge of wetlands (particularly water regimes);
- ground testing of the revised wetland maps produced by the current project, including attributing mapped wetlands with a wetland type;
- further investigation of mapping and references to wetlands in unpublished reports;
- investigation of the correlation between wetland type and abundance and land systems, such that land systems mapping might be used to estimate the extent of some types and be used in attributing wetlands that have been identified from satellite imagery;
- further biological survey of identified priority wetlands, including aerial bird survey;
- adequate resourcing of survey on Aboriginal Land, which typically involves longer planning times and funds to conduct meetings and engage traditional owners as consultants;
- establishing a list of plant species with high fidelity to wetlands in general or particular wetland types and the use of Herbarium specimen records to map or attribute wetlands;
- more detailed mapping of some wetlands using aerial photographs and satellite imagery;
- further study of inundation regimes using archival satellite imagery;
- actively maintaining a database of inventory level information about individual wetlands, building on the one created by this study.

Mapping and General Inventory

Additional wetland mapping data could be obtained from land resource assessment maps, and 1:50,000 scale orthophoto maps for some areas. Some of the important wetlands could be much better delineated with additional aerial photograph and satellite image interpretation. Finer scale mapping using these sources could be part of future wetland inventories of smaller areas, such as individual bioregions.

Collation is required of the coordinates, names and descriptions (including longevity) of individual waterholes and springs in aggregate sites that have been identified for potential inclusion in *A Directory of Important Wetlands in Australia*. These sites are the permanent waterholes of the Finke River, the Davenport Ranges waterholes and floodouts, the George Gill Range springs and waterholes, and the Dulcie Ranges springs and waterholes. There are some other wetlands that warrant further general inventory. This would include mapping individual water bodies and swamps in other wetland complexes, including the Elkedra floodout, and the Frew River floodout.

Additional information on the existence and attributes of specific wetlands undoubtedly exists in unpublished reports and local knowledge. Researchers undertaking future more detailed inventories of regions within the arid NT should not assume that these sources are all cited in this report. Resource appraisals of pastoral stations undertaken in the 1980s to assess applications for perpetual leases, are one of the sources not yet thoroughly searched. Others possible sources of additional information are reports on land resources, biological surveys and studies of water resources.

Detailed mapping of key wetlands using aerial photographs, satellite imagery and further consultation with local people, should be done. This will assist with improving knowledge of the general ecological function, hydrological regimes and inundation patterns of the wetlands.

Further investigation into the relationship between certain species of wetland plants and wetland types could result in a new tool for wetland inventory, based on Herbarium specimen records.

Priority areas for further general wetlands inventory are as follows:

- the upper Palmer River catchments - waterholes in the ranges and alluvial swamps;
- the far east of the MacDonnell Ranges bioregion;
- the floodouts of Skinner, Gastralobium and Yaddanilla creeks;
- the north western portion of the Tanami Bioregion;
- the Murchison Ranges;
- the area of the Tanami Desert west of the Murchison Ranges (including Porcupine Swamp);
- the Hanson River floodout;
- Lake Caroline;
- the Hay River floodout;
- the central Simpson Desert in the region of the borders with South Australia and Queensland;
- the Great Sandy Desert bioregion to the south and south-east of Lake Mackay;
- the far south west corner of the NT, to the south of the Petermann Ranges;
- various salt lakes in the far west of the NT: Lake Neale; Lake White; Lake MacDonald and Lake Albert.

Hydrological Regimes

Analysis of patterns of flow in arid NT rivers should be further researched. The existing stream gauging data provide a basis for this and might be supplemented with local knowledge of certain waterholes such as has been collated in this inventory.

Further investigation of the frequency of inundation of particular wetlands could be undertaken as part of a more detailed study of their ecology. This would involve further gathering of local knowledge, plus temporal analysis of satellite imagery of moderate to fine resolution. Landsat MSS data is available for up to three decades in some areas.

Further research is required to document the depth and duration of inundation in floodplains and floodouts, particularly those associated with the Sandover and Finke Rivers.

Priority should be given to documenting and mapping the permanency of waterholes and springs; particularly in the Davenport, Dulcie and MacDonnell Ranges. This would create a foundation for survey of other wetland values in those areas.

Bird Survey

There are still a great many gaps in our information on the importance of specific wetland types and specific wetlands for wetland birds. There have been quantitative total counts for a few wetlands from this and previous surveys, but the vast majority of bird records do not include abundance or are from counts of sections of wetlands only. As a result of this survey it has been possible to identify priority areas for future wetland bird survey. Using a combination of rainfall data and satellite images it would be possible to identify opportune times to visit particular areas. A substantial budget would be required for both helicopter and fixed wing aircraft. Helicopters would be essential to combine ground based calibration counts and species identifications with total wetland counts from the air. Sites should be targeted either opportunistically or as part of a follow up wetland bird survey program.

Total water body counts should be obtained for the various Newhaven Lakes to supplement the non-count records of birds. This might be achieved opportunistically with the combination of relatively good access to the lakes and claypans, and anticipated visitation by competent observers as a consequence of the purchase of Newhaven Station by Birds Australia.

Lake Lewis could be counted by boat or with aircraft. Total counts from this survey were made when the extent of water in the lake was significantly reduced. The lake was navigable by boat for 4 – 6 months in 2000 and for many months in 1974/5. Due to the limited vehicle access to the lake shore a helicopter could be used to assist with shore based counts if water depth does not permit use of an outboard motor.

Lake Amadeus is listed in a *Directory of Important Wetlands in Australia* but has not been aerially surveyed for birds. This should be a priority. Although the lake is generally shallower than the salt lakes with confirmed importance for wetland birds, its large size and numerous islands indicate potential importance. The same reasons indicate that the other large and poorly known salt lakes should be aerially surveyed for birds, including: Lake Neale; Lake White; Lake MacDonald and Lake Albert.

A number of the larger bluebush swamps should be targeted to assess the importance of this wetland type for birds. The abundance of cover and nesting sites in this wetland type indicate possible importance for the breeding of some species, although Northern Bluebush is less important for nesting than Lignum (R.Jaensch pers. comm.). Priority wetlands could include: Indinda and Casuarina swamps on Andado Station, Duffield swamp on New Crown Station, the two large swamps on the Burt Plain, just north of the West MacDonnell Ranges (Narwietooma and Milton Park Stations), the large swamp at Tarlton Downs, some of the many on Tobermorey Station and some of the large swamps on the Mitchell Grass Downs.

Total counts should be obtained for some of the Eucalypt wooded swamps. There are reports from property holders of large flocks of waterbirds in examples of this wetland type. Some of those surveyed in 2001 were subjectively assessed as having abundant and diverse waterbirds but few were systematically counted. Priority wetlands are Mud Hut Swamp on Stirling Station, the Elkedra and Frew River floodouts and Indemina swamp on Andado Station. Lake Surprise which includes areas of wooded swamp should be recounted at some stage, as part of ongoing biological assessment and monitoring in the region.

The Snake Creek Interdune Lakes should be recounted next time they are filled. They are among the longer lasting of the temporary NT wetlands due to their great depth and were virtually undocumented before this study.

Fish

The fish fauna of the Dulcie Ranges have not yet been systematically studied and may include isolated populations of *Neosilurus hyrtlui* and *Mogurnda sp.*, which are both relatively cryptic and could have eluded the relatively opportunistic survey conducted so far. Other possible species, not yet recorded from the Dulcies but recorded from the Sandover system on this survey are *Porochilus argenteus* and *Nematalosa erebi*. A systematic survey should be conducted with a variety of methods, including night fishing and preferably electro-fishing. Fish poison (e.g. rotenone) should not be used due to the low number of waterholes in each catchment and their generally disconnected state. The larger waterholes of the Ooratippa Creek system (part of the Sandover River system) should be given highest priority, including the one referred to as 'Rangey Bull Waterhole' by Latz and Langford (1983). The headwaters of Lucy Creek and the Plenty-Hay river system should be checked for the existence of any species in addition to *Leiopotherapon unicolor*.

The fish fauna of the Davenport and Murchison Ranges are better known than those of the Dulcies Ranges, but never-the-less warrant further study. The extremely brief and opportunistic sampling during this inventory added a species to those known from one of the creeks (*Neosilurus hyrtlui* in Kurundi Creek). The taxonomic status of the Davenport Ranges *Mogurnda* needs resolving. If it is found to be genetically distinct from *Mogurnda mogurnda* and *Mogurnda larapintae* it will have a high conservation significance. Fish survey work should be conducted in Skinner Creek. Numerous waterholes are marked on the 1:250,000 scale topographic map, but there is no information on permanency. Some are within a few kilometres of the Whistleduck Creek system and so it is possible that some are spring fed and permanent. Further survey is suggested for this creek as it may harbour additional species for the Western Drainage Division.

Fish Survey work should be conducted in Illara Waterhole which is one of the most permanent waterholes of the Finke River system. It is in a tributary of the Palmer River and is isolated from the other documented permanent and long lasting waters which are all on the mid to upper Finke River. There has been no systematic sampling of fishes occurring at Illara Waterhole. There may be other long lasting smaller rockholes in smaller tributaries of the Palmer River such as Petermann and Walker creeks and Bowson Waterhole further up Areyonga Creek from Illara Rockhole. All these areas warrant further survey work to establish fish distributions.

The occurrence and distribution of fishes in the Finke River is reasonably well known, but not the ecology. Particular emphasis is required on the Finke Goby (*Chlamydogobius japaipa*) which is listed as Vulnerable, to determine whether there is any threatening process at work.

Invertebrates

The invertebrate biodiversity of arid NT wetlands is very much under studied. Studies of waterholes in the West MacDonnell Ranges and the George Gill Ranges (Watarrka-Kings Canyon) have revealed each to have a distinctive fauna.

Work to improve knowledge of aquatic invertebrates will preferably involve repeated sampling through time, especially for temporary wetlands, since the aquatic invertebrate species assemblages can change through time in an inundation event. Further work is also required on the terrestrial invertebrate fauna that specialise in the substrate of playas when dry.

The highest priorities are the spring fed pools of the Dulcie Ranges, springs of the Treuer Range (Vaughan Springs, Eva Springs and others), permanent and semi-permanent waterholes of the Davenport and Murchison ranges and isolated rockholes, particularly those of the Great Sandy Desert bioregion. Other, more isolated, long-term permanent springs should be surveyed, including those on the south side of the Georgina Range in the East MacDonnell Ranges. Fresh water wetlands of lowlands (broadly: riverine waterholes, swamps and claypans) are the most heavily impacted by both weeds and introduced herbivores. Accordingly, study of their invertebrate life should be given a high priority and ideally will extend beyond documenting species occurrence to the study of broader ecology and the impacts of weeds and introduced herbivores.

Study of the aquatic fauna of salt lakes should be conducted, with comparison to the relatively well known salt lakes of arid South Australia, chiefly Lake Eyre.

The interactions and respective ranges of Inland Crab (*Holthusiana transversa*), Yabby (*Cherax destructor*) and Redclaw (*Cherax quadricarinatus*) warrant further investigation.

Improving Access to Species Distribution Records

Various databases of species distribution records exist at the state/territory and national levels, yet information is fragmented between many databases and can be difficult to access. It is important that existing initiatives to integrate databases are widely supported and in some cases extended, to assist with management and research of natural environments, including wetlands. However, in providing improved access to such information, it is important that information about the precise locations of environmentally sensitive organisms and sites be appropriately generalised. This includes sites where species may be poached, sites where quarantine from weeds and diseases is important and sites with cultural sensitivities. This may require the institutions involved to create parallel database fields for location coordinates and descriptions, with the more detailed information being only accessible by authorised researchers.

For plants, the situation is relatively well advanced with a project to create the Australian Virtual Herbarium. This involves databasing those state herbaria collections which are not databased and creating 'real-time' links to databases maintained by the various institutions, which will become accessible through a single internet site. Within the NT there is a need to establish an ongoing database of non-specimen species distribution records (including weeds), and this should be integrated into the Australian Virtual Herbarium as supplementary, non-vouchered data.

The situation is less advanced for fauna. Museums are the primary custodians of most preserved scientific animal specimens, and their collections are variously databased. A program called Australian Museums On Line maintains a collaborative internet access point to the major Australian Museums and will eventually incorporate specimen collection databases (http://amol.org.au/about_amol/about_amol.asp). Within the NT, the Parks and Wildlife Commission maintains a database of observational records of vertebrate fauna but does not include fishes. For invertebrates, the situation is far more complicated due to the generally poor level of taxonomic knowledge and the vast array of species.

Botanical Survey

There are several wetland areas which should be given a high priority for further botanical survey and documentation.

Warrabri Swamp at the floodout of the Skinner and Murray Creeks holds water for more than six months, but has never been surveyed botanically. Similarly, two other floodouts from the Davenport Range warrant further investigation, for which there is no information about longevity of inundation: Yaddanilla Creek and Gastralobium Creek.

Long lasting waterholes in the upper catchment of the Palmer River are very poorly known.

The various springs and waterholes in the catchments of the Hale River and Illogwa Creek, in the remote eastern areas of the East MacDonnell Ranges are poorly known. Any significant biota are likely to be plants but the possibility of significant invertebrates cannot be excluded.

All the known permanent and semi-permanent springs should be surveyed for plants including those on the south side of the Georgina Range in the East MacDonnells and those of the Treuer Range (Vaughan Springs, Eva Springs and others).

The waterholes and springs of the West MacDonnells, the James Range (Palm Valley Area), the George Gill Range (Watarrka National Park), the Dulcie Ranges, the Davenport Ranges and the Murchison Ranges are relatively well known in terms of species occurrence in each general area, but adequate species lists are not available for individual waterholes/springs in each area. Obtaining comprehensive species lists for individual waterholes and springs is justified given their general botanical distinctiveness. A database of this information is in preparation for the Watarrka sites (D. Schunke pers. comm.) and preliminary lists for some sites are available in White *et al.* (2000b).

Impacts of Various Wetland Uses by Humans

There is a need for further research on the impacts of human uses of wetlands, including use for grazing and watering domestic cattle. To get robust information that quantifies impacts is not easy and will require sustained long-term research. A collaborative approach between wetland users and various government departments and research institutions will be required to address the issues.

Research is required on the hypothesised adverse effects of personal chemicals polluting waterholes from swimmers; particularly sunscreen and insect repellent. A review of relevant monitoring and toxicological studies is necessary, as is design of a monitoring or research study of key waterholes such as the Garden of Eden on Kings Creek, Ellery Creek Big Hole, Glen Helen Waterhole, Redbank Waterhole and Ormiston Waterhole.

17.8 Recommendations for Listing Important Wetlands

The process of consultation with landholders about the possible listing of wetlands of national importance in the Directory, should be continued. This should not only result in most sites being listed, but also be a positive step in facilitating more active off-park conservation of wetlands.

Further survey and documentation of individual wetlands, within important wetland aggregates, may result in some of the individual wetlands being separately list in the Directory. For example, individual waterholes in the Finke River Headwaters site.

A process should be developed within the NT Government for nominating appropriate wetlands as Ramsar sites.



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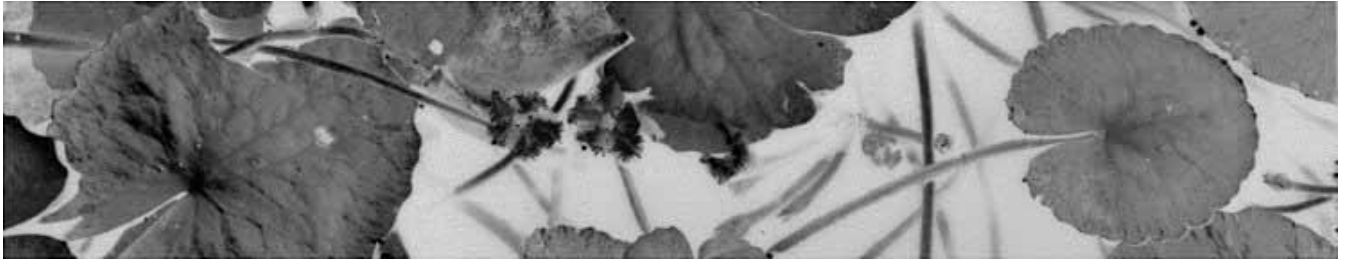
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Appendices



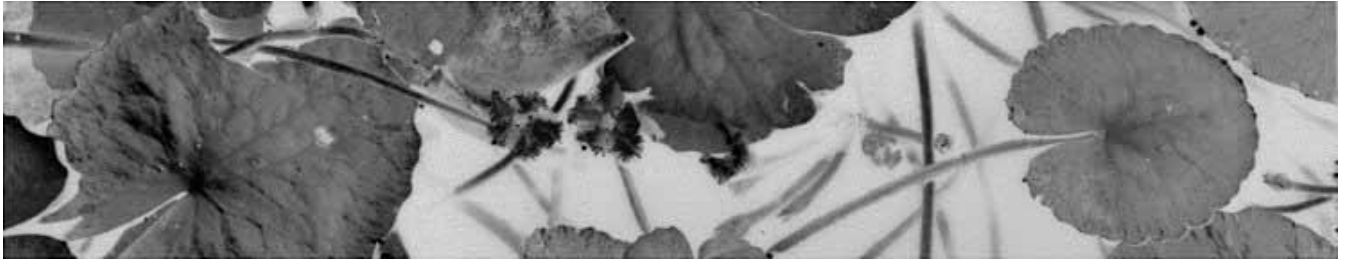
Appendix 1. Photographic Summary of Wetland Types and Features

stored as a separate PDF file



Appendix 2. Selected Wetland Maps and Satellite Imagery

stored as a separate PDF file



Appendix 3. Project Information Sheet



THE WETLANDS OF THE ARID NT

Inventory and Significance

The Parks and Wildlife Commission of the Northern Territory (PWCNT) has received funding from the Natural Heritage Trust for a project called 'Inventory and Significance of Wetlands in the Arid NT'.

This leaflet introduces the project to landholders and other interested parties. We are seeking to inform and involve landholders. Working with and learning from local people will be important to the success of the project.

The study region

The study region covers a large area of the Northern Territory from 20° latitude (roughly 40 kilometres south of Tennant Creek) to the South Australian, Queensland and Western Australian borders.

What is an arid zone wetland?

Wetlands is a term that can mean different things to different people. Our definition is based on international agreements and includes waterholes, rivers, swamps, clay pans, salt lakes and springs. It also includes artificial wetlands such as dams, sewerage ponds and bore drains.

Wetlands in the arid part of the Northern Territory range enormously in size from vast salt lakes to small spring fed pools. A few hold permanent water but most of the wetlands are dry most of the time. One of their distinguishing features is that following rain, they continue to hold water after the surrounding landscape has dried out. This stored water may be above the ground or in waterlogged soil and is important for some plants and animals.

Purpose of the project

There is very little documented information about wetlands in the arid zone of the Northern Territory. The project aims to determine:

- what sort of wetlands occur in the study region;
- where these wetlands are;
- how big these wetlands are;
- how many there are of each sort of wetland; and
- what plants and animals live in these wetlands.

There are wetlands of importance in the arid region of the Northern Territory including Lake Surprise, the Karinga Creek system, Lake Amadeus and the permanent waterholes in the headwaters of the Finke River. These wetlands are important for waterbirds and may act as refuges for a variety of wildlife. These wetlands have been listed in the 'Directory of Important Wetlands in Australia' which is maintained by the Commonwealth Government.

How will the project be conducted?

There are several stages to this project:

- collate existing information about wetlands in the arid region of the Northern Territory;
- develop a working classification of wetlands in the arid NT as a basis for choosing field sites to sample each sort of wetland;
- consult with landholders throughout the project;
- conduct field surveys to collect information about the different sorts of wetlands including what plants and animals they contain. Surveys will be at sites throughout the study region including areas identified by landholders. Aerial surveys will also be used to locate and map wetlands;
- use the results of the field surveys to map and classify the wetlands of the arid NT; and
- communicate the results of the study and produce a final report, which will discuss the significance of the different sorts of wetlands.

The study commenced in 1999. Field work will be carried out by Parks and Wildlife in 2000 and 2001 and the project will be completed by December 2001.

How can landholders be involved?

We would like landholders to be involved throughout the project. People on the land have valuable information about wetlands across the region and may have concerns about management issues such as weeds, feral animals or uncontrolled fire that may damage particular wetlands. Landholders are also welcome to accompany our survey team.

Contacts

If you would like more information about this project, or wish to discuss issues about wetlands in the arid NT, please contact us.

Angus Duguid (project leader)
ph: 8951 8240
email: angus.duguid@nt.gov.au

Helen Neave
ph: 8951 8227
email: helen.neave@nt.gov.au



Natural Heritage Trust
Helping Communities Helping Australia



Appendix 4. List of People Consulted

The following people were consulted regarding the nature of specific wetlands or wetlands in general during the survey. It is likely that a few may have been omitted; their assistance is nevertheless gratefully acknowledged.

Cattle station managers and /or lessees:

Robbie and Jo Bloomfield, Andado Station;
Tom Arnold, Rocklands Station;
Gill Bowman, Pine Hill Station;
Charlie Chalmers, Marqua Station;
Roy Chisholm, Napperby Station;
Andrew Clough, Epenarra Station;
Chris Connellan, Narwietooma Station;
Alex Coppock, Newhaven Station;
Donny Costello, Lilla Creek Station;
Garry Dann, Amburla Station;
Roy and Catherine Driver, Elkedra Station;
Laurie Facer, Manners Creek Station;
Alan and Jo Fogarty, Lucy Creek Station;
Clayton Green, Soudan Station;
Steve Hagan, Avon Dows Station;
Ray Jansen, Lake Nash Station;
Bernie Kilgarif, Erldunda Station;
Sean Leigh, Murray Downs and Aileron Stations;
Max Lines, Conniston Station;
David Martin, Mount Dennison Station;
Graham McDermot, Tobermorey Station;
Thomas McKay, Umbeara Station;
Peter Morphet, Horseshoe Bend Station;
Ian Morton, Glen Helen Station;
Leo Murphy & Helen Murphy, Idracowra Station;
David Roberts, Austral Downs Station;
Bill Sage, Stirling Station;
Peter Saint, Kurundi Station;
Doug Simms, Narwietooma Station;
John Stanes & Anne Stanes, Lyndavale Station;
Matthew and Vanessa Smith, New Crown Station;
Greg and Jo Vidler, Singleton Station.

Other non-NT Government People:

Mark Adams, South Australian Museum;
Keith Bellchambers, Hawker, South Australia;
Bernadette Bostock, Deakin University;
Dr Jenny Davis, Murdoch University;
Will Dobbie, Centralian Land Management Association;
Russell Fairfax, Queensland Herbarium, Department of Environment, Queensland;
Robert (Robbie) Henderson, Water Watch officer, Alice Springs;
Peter Hudson, University of Adelaide;
Roger Jaensch, Wetlands International;
Peter Latz, consultant and previously plant ecologist and botanist with Parks and Wildlife;
Bill Low, Low Ecological Services;

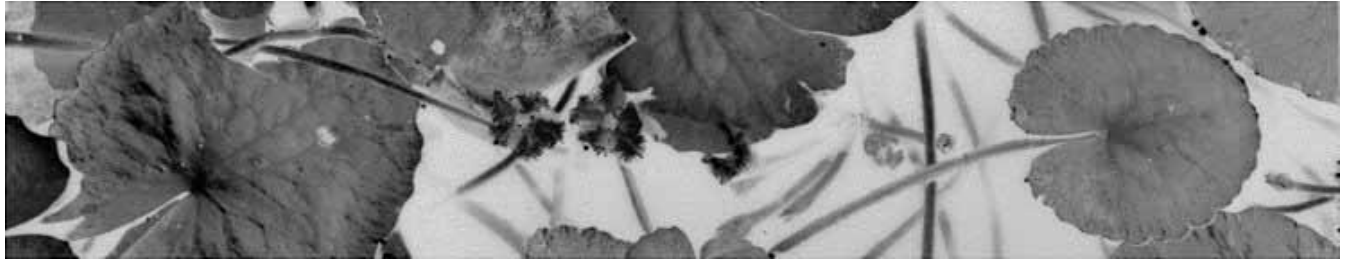
Henry Nix, Centre for Resource and Environmental Studies;
Bradley Nott, Central Land Council;
Dr. Jim Puckridge, University of Adelaide;
Stephen Reilly, Deakin University;
Terry Sim, South Australian Museum.

Staff of the Parks and Wildlife Commission of the NT (now within Department of Natural Resources, Environment and the Arts):

Michael Barritt (Ranger);
Chris Brock;
Jo Comber (Alice Springs Desert Park);
Chris Day (Chief District Ranger);
Dr Lynn Day (Zoologist and Bushcare coordinator);
Garry Fischer (Ranger);
Greg Fyfe (Alice Springs Desert Park);
Tim Hall (Senior Ranger);
Peter Horsfell (Horticulturist at the Alice Springs Desert Park);
Dr Ken Johnson (Regional Director);
Don Langford;
Pat Laughton;
Dennis Matthews (Senior Ranger);
Mark Richardson (Curator of Plants at the Alice Springs Desert Park);
Darren Schunke (Ranger);
Kim Schwartzkopff (Wildlife Ranger);
Cate Schmidt (Ranger);
Dr Jon Woinarski (Principal Scientist).

Other NT Government staff:

Grant Allan (Bushfire Council);
Keith Bethel (Bushfire Council);
Mandy Bowman;
John Childs;
Rick Dance (Primary Industries);
Dorsey Debney (Bushfire Council);
Fuller;
John Gavin (Weeds Officer);
Russell Grant;
Peter Jolley;
Alison Kennedy;
Robert (Bob) Read;
Graham Ride;
Diana Whitehouse.



Appendix 5. Summary of Survey Trips

Aerial survey: Karinga Lakes and Finke Gorge

21 July 2000, Angus Duguid, Megan McNellie & Roger Jaensch

Karinga Lakes & North Stuart Highway

22 - 25 July 2000 (4 days)

Angus Duguid, David Albrecht, Jeff Cole, Megan McNellie & Roger Jaensch (c.20 person-days)

number of sites: 12

Properties/regions surveyed & number of sites: Owen Springs Station (1), Erldunda Station (2), Lyndavale Station (2), Singleton Station (1), Neutral Junction Station (1), Stirling Station (5)

Lake Lewis & Napperby claypans

21 - 23 Sep 2000 (3 days), Angus Duguid & Robert Read (c.6 person-days), number of sites: 10

Properties/regions surveyed & number of sites: Napperby Station (10)

Albrecht opportunistic South East

27 - 28 Sep 2000, David Albrecht, number of sites: 3

Properties/regions surveyed & number of sites: Deep Well Station (1), Andado Station (2)

McNellie opportunistic South East

30 Sep - 3 Oct 2000, Megan McNellie and Theresa Nano, number of sites: 5

Properties/regions surveyed & number of sites: Ringwood Station (1), Andado Station (4)

Lake Mackay WA Opportunistic

22 Oct 2000, Peter Latz & Rachel Paltridge, number of sites: 1

Properties/regions surveyed & number of sites: Western Australia (1)

Lyndavale Opportunistic

27 Oct 2000, Jeff Cole, 1 site on Lyndavale Station

Henbury

5 - 7 Dec 2000 (3 days), Angus Duguid & Megan McNellie (c.6 person-days), number of sites: 15

Properties/regions surveyed & number of sites: Henbury Meteorites (1), Henbury Station (14)

Petermanns opportunistic 2000

11 - 14 Dec 2000, David Albrecht (c. 3 Person-days), number of sites: 3

Properties/regions surveyed & number of sites: Petermann Aboriginal Land Trust (3)

Newhaven

28 Feb - 4 Mar 2001 (5 days)

Angus Duguid, David Albrecht & Peter Latz (c.15 person-days), number of sites: 30

Properties/regions surveyed & number of sites: Newhaven Station (29), Mount Doreen Station (1)

Mt Skinner - Dulcies

3 - 10 April 2001 (8 days)

Angus Duguid, Jason Barnetson & David Albrecht (7-10 April only) (c.20 person-days)

Total sites for trip: 26

Properties/regions surveyed & number of sites: Mount Skinner Station (4), Ti Tree Station (1), Ammaroo Station (4), Derry Downs Station (4), Dulcie Ranges (4), Arapunya Station (7), Huckitta Station (1), Dneiper Station (1)

Finke River and Floodout

1 - 12 May 2001 (12 days)

Angus Duguid, Jason Barnetson, Stephen Ryan & Bernadette Bostock (c.48 person-days)

Total sites for trip: 64

Properties/regions surveyed & number of sites: Mac Clark Conservation Reserve within andado Station (1), Idracowra Station (11), Horseshoe Bend Station (9), Lilla Creek Station (5), Umbeara Station (4), New Crown Station (17), andado Station (17)

West Macs Fishing

16 & 22 May 2001 (2 days)

Bernadette Bostock, Stephen Ryan & Bruce. + Bernie Shakeshaft (16 April) & Jason Barnetson (22 April)

(c.7 person-days), number of sites: 5

Properties/regions surveyed & number of sites: West MacDonnell Ranges National Park (4), Owen Springs Station (1)

Alice Valley, Elkedra & Davenport

23 - 1 June 2001 (10 days)

Angus Duguid, Jason Barnetson, Stephen Ryan & Bernadette Bostock (c.36 person-days), number of sites: 37

Properties/regions surveyed & number of sites: Owen Springs Station (3), Annitowa Station (15), Elkedra Station (8), Ammaroo Station (1), Murray Downs Station (4), Davenport Ranges (5), Davenport Ranges National Park (1)

NE Burt Plain: Pine Hill to Narwietooma

14 - 23 June 2001 (10 days)

Angus Duguid, Jason Barnetson & Dawn Morgan (c.30 person-days), number of sites: 32

Properties/regions surveyed & number of sites: Pine Hill Station (12), Conniston Station (9), Napperby Station (7), Narwietooma Station (3), Amburla Station (1)

Northern Davenports and Barkly

24 July - 6 Aug 2001 (14 days)

Angus Duguid, Jason Barnetson, Jenni Risler, Dawn Morgan, David Albrecht[^] & John Westaway[^] ([^] = only for 24-27 July) (c.64 person-days), number of sites: 67

Properties/regions surveyed & number of sites: Singleton Station (7), Kurundi Station (6), Davenport Ranges (1), Epenarra Station (10), Soudan Station (8), Avon Downs Station (4), Rocklands Station (5), Austral Downs Station (13), Lake Nash Station (5), Georgina Downs Station (6), Argadargada Station (2)

Tanami opportunistic

14 - 16 Aug 2001 (3 days)

Peter Latz & Rachel Paltridge (c.6 person-days), number of sites: 5

Properties/regions surveyed & number of sites: Tanami Desert (5)

Plenty Highway and the far East

22 - 26 Aug 2001 (5 days)

Angus Duguid, Jason Barnetson & Jenni Risler (c.15 person-days), number of sites: 21

Properties/regions surveyed & number of sites: Manners Creek Station (4), Tobermorey Station (13), Marqua Station (1), Tarlton Downs Station (1), Lucy Creek Station (2)

Northern Burt Plain: Stirling & Aileron

28 Aug - 1 Sept 2001 (5 days)

Angus Duguid, Jason Barnetson, Jenni Risler & Naomi Briggs (c.20 person-days), number of sites: 22

Properties/regions surveyed & number of sites: Stirling Station (15), Annas Reservoir Conservation Reserve (1), Aileron Station (6)

Aerial bird survey: Lake Mackay

6 Sept 2001 (2 days)

Focussed on counting waterbirds on Lake Mackay but also included general wetland survey across parts of the Tanami, Great Sandy Desert and Burt bioregions, with aerial bird counts of lake Surprise, Lake Lewis and various lakes in the Central Mount Wedge area.

Hay River & Northern Simpson Desert Lakes

18 - 21 Sep 2001 (5 days)

Peter Latz, Michael Hewett, Michael Reiff and Robert Reiff (c.16 person-days)

Total sites for trip: 14

Properties/regions surveyed & number of sites: Simpson Desert (9), Atnetye Aboriginal Land Trust (5)

Lake Mackay ground

3 - 10 Oct 2001 (8 days)

Peter Latz, Rachel Paltridge (c.16 person-days); accompanied by Paddy Lewis Japanangka, Alice Michaels Nampitjinpa, Lindsay Turner Jampitjinpa, Mitjili Gibson Napanangka, Cindy Gibson Nakamarra and Letitia Bartlett Nungarrayi.

Total sites for trip: 17

Properties/regions surveyed & number of sites: Lake Mackay Aboriginal Land Trust (16), Mount Doreen Station (1)

Petermanns opportunistic 2001

4 Oct 2001, David Albrecht (c.1 person-days), number of sites: 4

Properties/regions surveyed & number of sites: Petermann Aboriginal Land Trust (4)

North East Simpson

24 - 28 Oct 2001 (5 days), Peter Latz & Robert Read (c.10 person-days), number of sites: 19

Properties/regions surveyed & number of sites: Tobermorey Station (18), Jervois Station (1)

Finke Interdune Floodout

5 - 10 Nov 2001 (6 days), Peter Latz & Robert Read (c.12 person-days), number of sites: 8

Properties/regions surveyed & number of sites: Mac Clark Conservation Reserve (1), andado Station (4), Simpson Desert (2), ERLDUNDA Station (1)

Alice Springs November Day Trips

Nov 2000, Peter Latz & Christopher Brock (c.2 person-days), total number of sites: 2

Properties/regions surveyed & number of sites: Alice Springs Shooting Club (1), Ringwood Station (1).



Appendix 6. Preliminary Classification of Arid NT Wetlands (superceded)

The preliminary (or working) classification was created in 2000 as a basis for field sampling. It was revised in the light of field work to create the final classification described in the main body of this report. The working classification is presented here since the database of wetland survey data includes numbers from the working classification where they were recorded in the field as part of a brief description of some wetlands.

BASINS (temporary lakes, ponds and swamps)

Freshwater, temporary, un-vegetated:

1. freshwater temporary large clay pan / lake [P] {B6}
 2. freshwater temporary large stony pan / lake [P] {B6}
 3. freshwater temporary small clay pan / pond [Ts] {B10}
 4. freshwater temporary small stony pan / pond [Ts] {B10}
- (drop 'large' if using lake and drop 'small' if using pond)

Saline, temporary, un-vegetated:

5. saline temporary large pan / lake - extensively salt-crustured when dry [R] {B8}
6. saline temporary large pan / lake - relatively uncrusted when dry [R] {B8}
7. saline temporary small pan / pond - extensively salt-crustured when dry [Ss] {B*?}
8. saline temporary small pan / pond - relatively uncrusted when dry [Ss] {B*?}

The terms pan, pond or lake to be chosen according to situation or local use. A basin wetland that is greater than 8 ha is a lake or a large pan. A basin wetland that is smaller than 8 ha is a pond or a small pan.

The term salt-crustured refers to the situation where salt crust is the dominant feature of the ground when dry. Uncrusted lakes/pans include those that have salt evident on the soil as white patches but not forming a generally continuous surface. The distinction between extensive salt crusted lakes and other saline lakes corresponds to the distinction between hypersaline and saline. Freshwater basins may extend into saline soils that exhibit some surface salinity making classification difficult when dry.

Freshwater, temporary, vegetated:

9. eucalypt wooded swamp [Xf] {B14? But not seasonal}
 10. acacia wooded swamp [Xf] {B13}
 11. melaleuca shrubby swamp [W] {B13}
 12. acacia/other shrubby swamp [W] {B13}
 13. lignum swamp [W] {B13}
 14. northern bluebush (*Chenopodium auricomum*) swamp [W] {B13}
 15. budda-pea/sesbania swamp (*Aeschynomene indica*, *Sesbania* spp.) [Ts] {B10}
 16. typha/phragmites swamp [Ts] {B10}
 17. canegrass swamp [Ts / W] {B10}
 18. other grass and sedge swamp (*Panicum*, *Cyperus*, *Eleocharis*) [Ts] {B10}
 19. forb swamp and meadow (*Cullen*, *Marsilea*) [Ts] {B10}
 20. Samphire freshwater swamp [Ts] {B10}
- (type 20. May be indistinct from claypans)

Saline, temporary, vegetated:

21. samphire saline swamp [Ss] {B11}

Flats (channel floodouts; terminal and non-terminal)

Stream flood-out areas (terminal or sub-terminal)

22. wooded flood-out flat (or 'wooded/shrubby flood-out flat') [Xf] {B4 / B14? But not seasonal}
 23. grassy flood-out flat [Ts] {B4}
 24. bare flood-out flat (clay-pan like but less defined edges associated with floodout area) [Ts] {B4}
- (note: if major channels present, use 'wooded water course')

Preliminary Classification continued:

SPRINGS including Spring Fed Pools & Soaks

25. soak (spring fed water-logged area) [Y/Ts] {B17/B9}
26. mounded artesian spring [Y/Ts] {B17/B9}
27. un-mounded artesian spring [Y/Ts] {B17/B9}
28. spring-fed rock hole (see also below) [Y/Tp] {B17/B9}

SMALL ROCK BASINS AND HOLES

29. upland non-watercourse rock-hole (not spring fed; see above) [Ts] {B10}

CHANNELS

Persistent Waterholes in Drainage Lines

30. permanent waterhole in lowland watercourse *f* [Tp] {B9/B2}
31. permanent waterhole in upland watercourse ** (assoc. With ranges) [Tp] {B9/B2}
32. semi-permanent waterhole in lowland watercourse [Ts/N] {B10/B2}
33. semi-permanent waterhole in upland watercourse ** [Ts/N] {B10/B2}

(permanent = never dry; semi- permanent =dry in drought only)

(*f* no distinction is made between those in gaps in major ranges, those at the base of ranges and others. This may be a desirable modification according to Jenny Davis' report on the Waterholes of the West MacDonnell Ranges (Davis, 1995)

(** or 'gully')

Not persistent (= temporary) Waterholes in Drainage Lines

34. temporary waterhole in lowland watercourse [Ts/N] {B10/B2}
35. temporary waterhole in upland watercourse** [Ts/N] {B10/B2}

(Not persistent = temporary)

(** or 'gully')

Not persistent (= temporary) Drainage Lines (excluding waterholes)

36. eucalypt wooded watercourse (may have multiple channels) [N] {B2}
37. acacia wooded watercourse (may have multiple channels) [N] {B2}
38. melaleuca shrubby watercourse [N] {B2}
39. other shrubby watercourse (lignum, acacia-shrubs) [N] {B2}
40. watercourse without trees and shrubs (grassy, bare) [N] {B2}

SUB TERRANEAN

41. karst care wetlands (limestone country) [Zk(b)] {B19}
- (note: none documented)

ARTIFICIAL

42. stock dams and tanks [2/6] {B2}
43. water storage reservoirs [6] {B1}
44. sewage ponds and outflow swamps [8/Ts] {B6}
45. bore overflow and drain swamps [?Ts] {?}



Appendix 7. Ramsar Wetland Definition, Classification and Criteria for Internationally Important Wetlands

Ramsar Definition of a Wetland

Definition

Under the Convention on Wetlands (Ramsar, Iran, 1971) 'wetlands' are defined by Articles 1.1 and 2.1 as shown below:

Article 1.1:

'For the purpose of this Convention wetlands are 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.'

Article 2.1 provides that wetlands:

'may incorporate riparian and coastal zones adjacent to the wetlands, and islands or bodies of marine water deeper than six metres at low tide lying within the wetlands'.

Ramsar Wetland Classification

The wetland types listed below are from the

'Ramsar Classification System for Wetland Type as approved by Recommendation 4.7 and amended by Resolution VI.5 of the Conference of the Contracting Parties. The categories listed herein are intended to provide only a very broad framework to aid rapid identification of the main wetland habitats represented at each site.'

Marine/Coastal Wetlands – not listed here

Inland Wetlands

L -- Permanent inland deltas.

M -- Permanent rivers/streams/creeks; includes waterfalls.

N -- Seasonal/intermittent/irregular rivers/streams/creeks.

O -- Permanent freshwater lakes (over 8 ha); includes large oxbow lakes.

P -- Seasonal/intermittent freshwater lakes (over 8 ha); includes floodplain lakes.

Q -- Permanent saline/brackish/alkaline lakes.

R -- Seasonal/intermittent saline/brackish/alkaline lakes and flats.

Sp -- Permanent saline/brackish/alkaline marshes/pools.

Ss -- Seasonal/intermittent saline/brackish/alkaline marshes/pools.

Tp -- Permanent freshwater marshes/pools; ponds (below 8 ha), marshes and swamps on inorganic soils; with emergent vegetation water-logged for at least most of the growing season.

Ts -- Seasonal/intermittent freshwater marshes/pools on inorganic soils; includes sloughs, potholes, seasonally flooded meadows, sedge marshes.

U -- Non-forested peatlands; includes shrub or open bogs, swamps, fens.

Va -- Alpine wetlands; includes alpine meadows, temporary waters from snowmelt.

Vt -- Tundra wetlands; includes tundra pools, temporary waters from snowmelt.

W -- Shrub-dominated wetlands; shrub swamps, shrub-dominated freshwater marshes, shrub carr, alder thicket on inorganic soils.

Xf -- Freshwater, tree-dominated wetlands; includes freshwater swamp forests, seasonally flooded forests, wooded swamps on inorganic soils.

Xp -- Forested peatlands; peat swamp forests.

Y -- Freshwater springs; oases.

Zg -- Geothermal wetlands

Zk(b) – Karst and other subterranean hydrological systems, inland

Note : ‘floodplain’ is a broad term used to refer to one or more wetland types, which may include examples from the R, Ss, Ts, W, Xf, Xp, or other wetland types. Some examples of floodplain wetlands are seasonally inundated grassland (including natural wet meadows), shrublands, woodlands and forests. Floodplain wetlands are not listed as a specific wetland type herein.

Human-made wetlands

1 -- Aquaculture (e.g. fish/shrimp) ponds

2 -- Ponds; includes farm ponds, stock ponds, small tanks; (generally below 8 ha).

3 -- Irrigated land; includes irrigation channels and rice fields.

4 -- Seasonally flooded agricultural land (including intensively managed or grazed wet meadow or pasture).

5 -- Salt exploitation sites; salt pans, salines, etc.

6 -- Water storage areas; reservoirs/barrages/dams/impoundments (generally over 8 ha).

7 -- Excavations; gravel/brick/clay pits; borrow pits, mining pools.

8 -- Wastewater treatment areas; sewage farms, settling ponds, oxidation basins, etc.

9 -- Canals and drainage channels, ditches.

Zk(c) – Karst and other subterranean hydrological systems, human-made

Reprinted from the ‘Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance’.

Criteria for Identifying Wetlands of International Importance (Ramsar Sites)

The Criteria for Identifying Wetlands of International Importance as adopted by the 4th, 6th, and 7th Meetings of the Conference of the Contracting Parties to the Convention on Wetlands (Ramsar, Iran, 1971) to guide implementation of Article 2.1 on designation of Ramsar sites. [Note: This is just a simple list of the Criteria themselves out of their explanatory settings. They should properly be used as part of the Strategic Framework and guidelines for the future development of the List of Wetlands of International Importance adopted by COP7, 1999.]

Group A of the Criteria. Sites containing representative, rare or unique wetland types

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.

Group B of the Criteria. Sites of international importance for conserving biological diversity

Criteria based on species and ecological communities

Criterion 2: A wetland should be considered internationally important if it supports vulnerable, endangered, or critically endangered species or threatened ecological communities.

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.

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.

Specific criteria based on waterbirds

Criterion 5: A wetland should be considered internationally important if it regularly supports 20,000 or more waterbirds.

Criterion 6: A wetland should be considered internationally important if it regularly supports 1% of the individuals in a population of one species or subspecies of waterbird.

Specific criteria based on fish

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.

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.



Appendix 8. Guide to Wetland Oriented Organisations

The following organisations are involved with wetlands in Australia and are either involved in the arid NT or have activities or policies that are relevant to the arid NT. This is not a definitive list; other organisations of relevance may have been inadvertently left out and government departments, museums, universities and similar research institutions have not been included. The list is ordered in loosely defined groups: wetland focussed organisations; specialist biota/scientific bodies; and conservation organisations.

Ramsar Organisation. The Ramsar Convention is administered by the secretariat, or Bureau of the Convention on Wetlands which maintains a website at <http://www.ramsar.org/>.

Wetlands International. Wetlands International is a leading global non-profit organisation dedicated to wetland conservation and sustainable management. It is a formal part with the Ramsar organisation and has responsibility for maintaining the list of wetlands of international importance (Ramsar sites). There is an Australian office of the Oceania Programme of Wetlands International.

Water Watch (www.waterwatch.org.au): Waterwatch Australia is a national community water monitoring program, initiated by the Commonwealth Government in 1993.

Land and Water Resources Research and Development Corporation (LWRRDC). LWRRDC is a Commonwealth Government body that identifies and funds research aimed at increasing the sustainability of national land, water and vegetation use.

Wetland Care Australia. Wetland Care Australia (formerly Ducks Unlimited Australia) is a not-for-profit community organisation dedicated to conserving Australia's wetlands. Website: www.wetlandcare.com.au

Inland Rivers Network. The Inland Rivers Network is a network or groups involved with conservation of the Murray River system, including wetlands. Website: www.nccnsw.org.au/member/wetlands

Birds Australia. Birds Australia (formerly the Royal Australian Ornithological Organisation) is the peak Australian body for amateur and professional ornithological studies. Website: www.birdsaustralia.com.au
There are two special interest groups within Birds Australia that are focussed on waterbirds: the Australasian Wader Studies Group (AWSG); and the Australasian Seabird Group. AWSG produces a biannual journal - *The Stilt* – and a quarterly newsletter – *The Tattler*.

Native Fish Australia (NFA). NFA is an volunteer organisation dedicated to the well-being of Australian native fish and their habitats. The NFA website includes links to many other fish and wetland related Australian internet sites, including groups focussed on aquarium and recreational fishing.
Website: www.nativefish.asn.au

Australian Society for Fish Biology (ASFB). The ASFB is a professional body of fish biologists. It maintains a list of threatened Australian fishes. Website: www.asfb.org.au

Australian Society for Limnology (ASL). The ASL is a scientific society, whose focus is the study and management of inland waters. It has several wetland related policies, available on its web pages. Website: www.asl.org.au. The ASL has several wetland related policies, available on its web pages (internet site for ASL): A 'Wetlands Policy Document';

- (20/9/99 [asl_wetlands_poldoc.htm](#));
- 'A Dryland Rivers Policy Document' (20/9/99 [asl_dryland_poldoc.htm](#)); and
- 'Australia's Aquatic and Wetland Resources: the Critical Challenges' (25/9/01 [asl_poldoc_challenges.htm](#)).
- proceedings of 'The Australian Wetland Forum', convened in July 2000, in partnership with the World Wide Fund for Nature (WWF). The aim of the forum was to comment on wetland policies, programs and actions (internet site for ASL: [asl_wetlandforum.htm](#)).
-

Conservation Volunteers Australia (formerly Australian Trust for Conservation Volunteers - ATCV). Currently has a major wetland program – **Revive our Wetlands** - with corporate sponsorship.
Website: www.atcv.com.au/revive/index.htm.

Threatened Species Network (TSN). The Threatened Species Network (TSN) is a joint program of WWF and the Natural Heritage Trust. TSN's aim is to increase public awareness of, and involvement with, the protection and recovery of threatened Australian species and their habitats. Website: www.wwf.org.au

Australian Network for Plant Conservation (ANPC). The ANPC is a network of individuals and organisations involved in plant conservation in Australia.
Website: www.cpbr.gov.au/anpc

World Wide Fund for Nature (WWF). WWF (formerly World Wildlife Fund) is an international non-government conservation organisation that has several Australian offices, including a wetlands officer for northern Australia, based in Kununurra. Website: <http://www.panda.org> & <http://www.wwf.org.au/>.

IUCN – The World Conservation Union. The IUCN is an international union of governments and other organisations and has developed criteria for assessing the conservation status of species that have been adopted for use by the Northern Territory Government in assessing the status of species under the Territory Parks and Wildlife Act. Website: www.iucn.org

Australian Conservation Foundation (ACF). The ACF is one of Australia's leading national, non-government environment and conservation lobby groups.

Greenpeace. Greenpeace is an international environment and conservation lobby group.



Appendix 9. Survey Data Proformas

Site: _____ Date: _____ Observer(s) Names: _____

Site Type: (Rapid / Detailed) _____ Map Sheet (1:250k): _____

Wetland Name/s: _____

(source codes: M=map name, L=local, S=survey new name) _____

Location (property name, distance and direction from named place on 1:250,000 top map) _____

UTM Zone: 52 / 53 _____ east _____ north Altitude: _____ metres a.s.l

Latitude: ____ ° ____ ' ____ " Longitude: ____ ° ____ ' ____ " Datum: AGD66 / other: _____

Position method: GPS / Map PDOP: _____ Map Scale: _____ Position accuracy estimate: +/- _____ m

Relative Position Comment/Offset : _____

Comments on access: _____

Size of wetland (estimated dimensions): _____ by _____

Proportion of wetland observed: _____ / or Dimensions of area observed: _____ (area seen, not quadrat size)

Observation method: ground / boat / hill / aircraft / driveby & edge / area (circle appropriate option/s)

Mapped on 1:250,000 topo map: Y / N Adequacy of Mapping: _____

Proportion of Wetland Inundated: _____ % Depth estimate: _____ current and/or _____ maximum

Water character if present: Colour: _____ Turbidity: clear / low / medium / high
turbidity

(eg. Clear / yellow brown / milky brown / other)

Flow speed: Still / Slow / Fast Water conductivity: _____ Lab / Field Water PH: _____ Lab / Field

DLPE H₂O No: _____ Algal growths in water – comment: _____

Water persistence: Permanent / Longterm / Temporary / no data

Other Information on inundation events/frequency and information sources:

Catchment/Hydrology of the wetland (describe):

General Description, uniformity, patterning, information from local or other knowledge of the wetland:

Wetland Type(s): Type from Working Classification	Proportion (%)
Dominant Type: _____	_____
Other Types: _____	_____
_____	_____
_____	_____
_____	_____

Earthworks or other mechanical modifications (describe):

Lists/comments regarding species seen: plants, fish, waterbirds, other birds, invertebrates, frogs:

Fish: seen / not seen / listed Aquatic Invertebrates: seen / not seen Waterbirds: seen / not seen / listed

Invertebrates – No. Of samples _____ Plant List: Full / Partial

Adjacent & Nearby Landforms and Vegetation Types:

Description of photographs taken/photo number:

Time spent on survey at site: _____ person hours / minutes (circle appropriate option)

Sketch shape of wetland, arrangement of sub-habitats, dimensions, and position of adjacent landforms: Y / N

Wetlands Survey Rapid Sites - Physical and Vegetation Data

Site: _____ Date: _____ Observers Initials: _____

Extent of visible salting on surface of ground within wetland: _____ % (estimated average for entire dry part of wetland)

Surface Soil Wet : Y / N Thickness of salt crust if extensive: _____

If not describing sub-habitats separately, estimate substrate *ignoring live plants & litter*:

_____ % est. Surface soil ground + _____ % loose rock + _____ % outcropping rock = 100% of entire site / dry part
(circle)

Soil description (colour, estimated texture, cracking, thickness of inorganic crust):

Disturbances - rate from 0 (nil) to 5 (major impact): Weeds _____ Rabbits _____ Horses/Donkeys _____ Camels _____ Cattle _____

Fire evidence: _____ Estimated time since fire: _____

Other disturbance: _____

Vegetation condition: shrubs & trees stressed forbs stressed fresh growth no stress

seedlings present drowned dead shrubs

Plants (particularly dominant or characteristic plants - eg. RedGum, Coolibah, Lignum, Reeds, Rushes, Sedges, Nardoo):

Weed Species:

Vegetation structure – Dominants by layer (fill in for each sub-habitat if full site):

surface soil soil wetness codes: D = dry, M = moist, S = saturated

Code	Name	Description: including dominant plants & spatial arrangement of habitats	% of wetland	% soil	% loose stone	% outcrop rock	% surface water	Surface soil wetness D/M/S

Site:	Date:	Page:	Observers Initials:	
Abundance Code	Rare - very few individuals = R (1 - 5 plants in 50 x 50m) (<1 plant in 10 X 10m)	Few/Occasional individuals = F (6 - 50 plants in 50 x 50m) (1-2 plants in 10 X 10m)	common to abundant = A (>= 50 in 50 x 50m) (> 2 plants in 10 X 10m)	unexpected = U (ie a ring-in and not at all typical of sub-habitat)

Cover Class	1 = 0 - 10% = 1	10 - 30% = 2	30 - 70% = 3	> 70% = 4
--------------------	------------------------	---------------------	---------------------	------------------

*Write in sub-habitat codes → → → → *Quadrat/Search Area Dimensions → → → → *Species list Complete / Partial / Dominants Ony → →	1 st sub-hab:	2 nd sub-hab:	3 rd sub-hab:	4 th sub-hab:	5 th sub-hab:	6 th sub-hab:

Plant Species/Field Name/ Collectors Voucher Number	ID by	cover (A,B, or C) & abundance codes (1-4)				
---	-------	---	--	--	--	--

Eg <i>Exemplus exemplii</i>	AD	A3	-	-	R1	
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
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44						
45						
46						
47						
48						
49						
50						

Site: _____ Date: _____ Page: _____ Observers Initials: _____

Abundance Code	Rare - very few individuals = R (1 – 5 plants in 50 x 50m) (<1 plant in 10 X 10m)	Few/Occasional individuals = F (6 – 50 plants in 50 x 50m) (1-2 plants in 10 X 10m)	common to abundant = A (>= 50 in 50 x 50m) (> 2 plants in 10 X 10m)	unexpected = U (ie a ring-in and not at all typical of sub-habitat)
----------------	---	---	---	---

Cover Class	1 = 0 – 10 % = 1	10 – 30 % = 2	30 – 70 % = 3	> 70 % = 4
-------------	-------------------------	----------------------	----------------------	-------------------

Plant Species/Field Name/ Collectors Voucher Number write in sub-habitat codes → → → & observer's initials	ID by:	1 st sub-hab:	2 nd sub-hab:	3 rd sub-hab:	4 th sub-hab:	5 th sub-hab:	6 th sub-hab:
Eg <i>Exemplus exemplii</i>		A3	-	-	R1		
52							
53							
54							
55							
56							
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95							

Mark number seen and suffix with 'b' if breeding b (eg presence of chicks)

Great crested Grebe

Hoary-headed Grebe

Australasian Grebe

unidentified grebes

Australian Pelican

Darter

Great Cormorant

Pied Cormorant

Little Black Cormorant

Little Pied Cormorant

unidentified cormorants

White-necked Heron

White-faced Heron

Cattle Egret

Great Egret

Little Egret

Intermediate Egret

unidentified egrets

Nankeen Night Heron

Glossy Ibis

Australian White Ibis

Straw-necked Ibis

Royal Spoonbill

Yellow-billed Spoonbill

unidentified spoonbills

Wandering Whistling-Duck

Plumed Whistling-Duck

Black Swan

Freckled Duck

Pacific Black Duck

Grey Teal

Chestnut Teal

Australasian Shoveler

Garganey

Pink-eared Duck

Hardhead

Australian Wood Duck

Blue-billed Duck

unidentified ducks

Osprey

Swamp Harrier

Buff-banded Rail

Baillon's Crake

Australian Spotted Crake

Spotless Crake

Black-tailed Native-hen

Dusky Moorhen

Purple Swamphen

Eurasian Coot

Brolga

Painted Snipe

Masked Lapwing

Banded Lapwing

Grey Plover

American Golden Plover

Red-kneed Dotterel

Greater Sand Plover

Oriental Plover

Red-capped Plover

Black-fronted Dotterel

Black-winged Stilt

Banded Stilt

Red-necked Avocet

Ruddy Turnstone

Whimbrel

Little Curlew

Wood Sandpiper

Green Sandpiper

Grey-tailed Tattler

Common Sandpiper

Common Greenshank

Marsh Sandpiper

Swinhoe's Snipe

Black-tailed Godwit

Bar-tailed Godwit

Sharp-tailed Sandpiper

Pectoral Sandpiper

Little Stint

Red-necked Stint

Long-toed Stint

Curlew Sandpiper

Broad-billed Sandpiper

Ruff

Red-necked Phalarope

Oriental Pratincole

Australian Pratincole

unidentified waders (incl. Sandpipers & plovers)

Silver Gull

Whiskered Tern

White-winged Black Tern

Gull-billed Tern

Caspian Tern

unidentified terns

Clamorous Reed-Warbler

Little Grassbird

Yellow Chat

Σ

Total Number Species:

Sub habitat soils, vegetation structure and condition sheet
(used at a subset of sites to record additional information for a separate vegetation mapping activity)

Site: _____ Date: _____ Page: _____ Observers Initials: _____

Sub-habitat Code/Name: _____

Quadrat Dimensions: _____ m x _____ m or area if irregular shape _____ m²

Size/Dimensions of patch of sub-habitat: _____

Location Details (where different from those on the main site sheet):

UTM Zone: 52 / 53 _____ east _____ north Altitude: _____ metres a.s.l

Latitude: _____ ° _____ ' _____ ' Longitude: _____ ° _____ ' _____ ' Datum: AGD66 / other: _____

Position method: GPS / Map PDOP: _____ Map Scale: _____ Position accuracy estimate: +/- _____ m

Ground Cover Seen (✓=100%):

Exposed Soil &Crust	%
Exposed Rock & Stone	%
Live Ground Vegetation	%
Exposed Litter	%

No. Logs > 15cm diam. _____

PH of Biogenic soil crust: _____

Crust Colour(s): black green clear

Disturbances - rate from 0 (none evident) to 5 (major impact)

Weeds	
Rabbits	
Horses/Donkeys	
Camels	
Cattle	
Fire	
Other	

Substrate – estimated actual (✓=100%):

Salt Crust	%
Biogenic soil crust	%
Bare Soil	%
Loose Rock & Stones	%
Outcropping Rock	%

Thickness of salt crust if extensive: _____

Estimated time since fire _____

Termite mounds (no.): _____

Max. Ht.: _____ m

Profile: tower / dome / underground

Lithology:

Rock Sizes (% of total rock cover):	Pebbles (<0.6cm):	0 <2 2-10 10-20 20-50 50-70 70-90 >90
	Small stones (0.6-2cm):	0 <2 2-10 10-20 20-50 50-70 70-90 >90
	Stones (2-6cm):	0 <2 2-10 10-20 20-50 50-70 70-90 >90
	Small rocks (6-20cm):	0 <2 2-10 10-20 20-50 50-70 70-90 >90
	Rocks (20-60cm):	0 <2 2-10 10-20 20-50 50-70 70-90 >90
	Big rocks (60cm-2m):	0 <2 2-10 10-20 20-50 50-70 70-90 >90
	Boulders (>2m):	0 <2 2-10 10-20 20-50 50-70 70-90 >90
	Outcrop/slab:	0 <2 2-10 10-20 20-50 50-70 70-90 >90

Vegetation condition: shrubs & trees stressed forbs stressed fresh growth no stress
seedlings present drowned dead shrubs

Strata	Dominant species (in order of dominance)	Average ht. (m) of strata	Cover (%) of strata (<10 10-30 30-70 >70 or %)
Emergent tree layer:			
Upper shrub layer: (> 2m)			
Lower shrub layer: (1 – 2 m)			
Ground layer: (< 1m)			

VEGETATION PROFILE (% COVER IN HEIGHT CLASSES)	Notes:
>10m: 0 <5 5-10 10-30 30-50 50-70 >70	
5-10m: 0 <5 5-10 10-30 30-50 50-70 >70	
3-5m: 0 <5 5-10 10-30 30-50 50-70 >70	
1-3m: 0 <5 5-10 10-30 30-50 50-70 >70	
0.5-1m: 0 <5 5-10 10-30 30-50 50-70 >70	
0-0.5 m: 0 <5 5-10 10-30 30-50 50-70 >70	

Soils Data

Minimal Soils Data:

Estimated Soil texture: sand / sandy-loam / loam / clay-loam / clay / cracking clay / rock / other:

Detailed Soils:

Surface Cracking Clay Crust: Y / N thickness: _____

Soil Pit Depth: _____ Comment on Horizons, Stoniness, Presence of Crystals, Calcareous nodules, Mottles:

General Description:

Samples:

Depth	Sample Kept	Munsel Colour Moist Hue Val Chr	pH	Texture	Coarse Frag %	CO ₃	Conductivity L = lab F = field