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Framework for assessing the values of waterbirds in the Alligator Rivers Region, northern Australia

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Contents

Tables

Figures

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1 Introduction

Waterbirds are a widely recognised ecological value of the wetlands that occur across northern Australia, with those in the Alligator Rivers Region being highly regarded (Bamford 1988a, 1990; Bayliss & Yeomans 1990, Saalfeld 1990, Morton et al 1990a,b, 1991, 1993a,b, Chatto 2000b, 2001, 2003). Given the importance attributed to waterbirds we aim to collate and assess existing information to determine its usefulness as a knowledge base for making decision about protecting the ecological integrity of wetlands in the Alligator Rivers Region. The Alligator Rivers Region as defined in the *Environment Protection (Alligator Rivers Region) Act 1978* includes the catchments of the West Alligator, South Alligator and East Alligator Rivers and some additional areas within Kakadu National Park (fig 1).

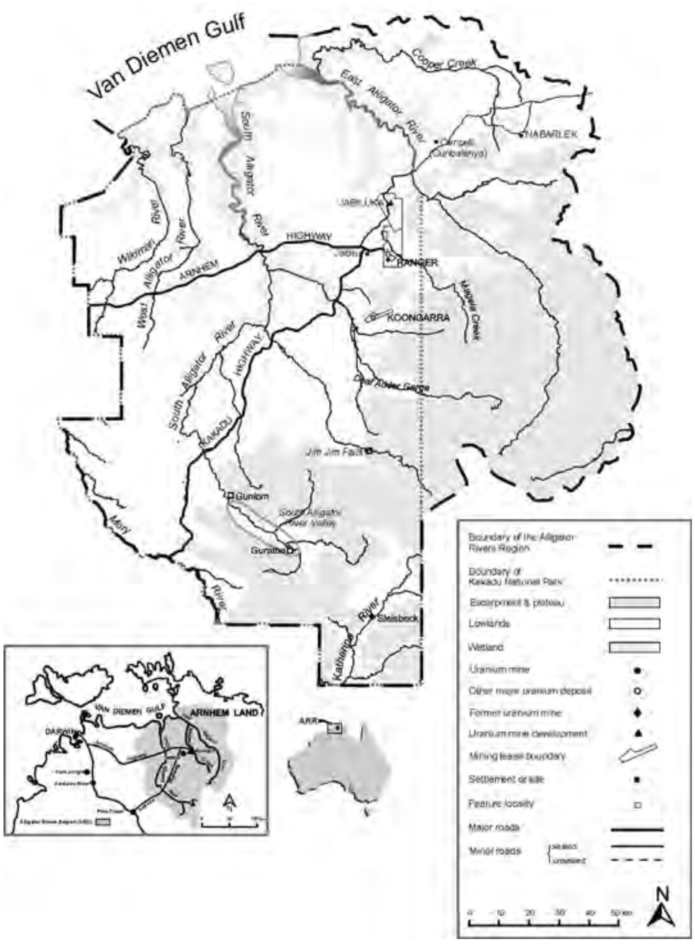

Figure 1 The Alligator Rivers Region in Australia's Northern Territory. The boundary of Kakadu National Park, within the Region, is indicated.

The rich natural resources of the Region have sustained human habitation for at least 25 000 years and possibly 40 000 to 60 000 years (Commonwealth of Australia 1999). Indigenous people own much of the land in the Region and continue to use its natural resources in a traditional manner. Other non-indigenous land uses have been varied and dynamic over the years. Pastoralism, gold (in the past) and uranium mining have long been dominant land uses within the Region and adjacent land, while conservation and tourism have emerged as more recent influences (Spiers 2000).

The Aboriginal art sites of Kakadu National Park are a unique artistic record of human interaction with the environment over tens of thousands of years. The natural ecosystems of the Park are recognised under international conservation conventions. As such, Kakadu National Park is listed as a World Heritage Area for both its natural and cultural heritage values and is also listed under the Ramsar Wetlands convention (Finlayson & von Oertzen 1996). Because of the significance attached to Kakadu National Park by the Australian and international communities, the Commonwealth Government established a unique regime for environmental protection.

Uranium mining has been part of the Alligator Rivers Region for nearly fifty years and since 1978 the Supervising Scientist has conducted audits, inspections, environmental monitoring and research, and provided technical advice, to ensure that the environment of the Region is protected from the effects of uranium mining to the very high standard required by the Commonwealth Government and the Australian people (Humphrey et al 1999, Supervising Scientist 2002). Nevertheless, mining does not represent the only potential threat to the natural values of the Region, and the World Heritage values of Kakadu National Park in particular: for example, tourism, climate change, fire and invasive plants and animals, with many of these operating on a wide front across the broader landscape, also represent potential threats (Humphrey et al 2002).

Kakadu National Park is managed jointly by Parks Australia, and Aboriginal landowners (Lawrence 2000). Through its staff and consultants, Parks Australia, in consultation with landowners, conducts research and monitoring, such as those for weeds and feral animals control, rare and threatened species, and fire management (Parks Australia North 1999). The results of investigations undertaken by Parks Australia and the Supervising Scientists are being used to assess the extent to which the World Heritage and Ramsar values of the Park, and in general the natural values of the Alligator Rivers Region, are being maintained, with the latter focussing on the potential effects of uranium mining activities in the Region.

2 Background : landscape-catchment scale research

Following approval by the federal government for the establishment of a new uranium mine at the Jabiluka Mineral Lease, in the Alligator Rivers Region, the Bureau of the World Heritage Committee (WHC) sent a mission to Kakadu to establish whether or not the World Heritage values of Kakadu were under threat from the Jabiluka Project.

The Mission noted that there was an unacceptably high degree of scientific uncertainty relating to the Jabiluka mine design, tailing disposal and possible impact on catchment ecosystems. As a consequence, in their report, submitted to the Bureau of the World Heritage Committee at its meeting held in Kyoto, Japan, on 27–28 November 1998, the Mission recommended that the mining and milling of uranium should not proceed.

Further to this recommendation, the World Heritage Committee requested that the Supervising Scientist conduct a full review of the areas of scientific uncertainty. The major issues requiring review included: extent of hydrological modelling; prediction and impact of severe weather events; storage of uranium ore on the surface; and the long-term storage of mine tailings.

The report submitted by the Supervising Scientist (Johnston & Prendergast 1999) in response to this request, was reviewed by an Independent Science Panel (ISP) of the International Council for Science Unions (ICSU), and the World Conservation Union (IUCN), acting on behalf of the World Heritage Committee. The ISP and IUCN concluded that impacts from the site-specific Jabiluka proposal were most likely very small or negligible (Independent Science Panel 2000). Nevertheless, the ISP recommended a more comprehensive risk assessment of both freshwater and terrestrial ecosystems at a landscape-catchment scale, as the Region is subject to change or variability due to other influences such as: climate, land use and introduced species which may be unrelated to mining activity but could synergistically or cumulatively interact with mining activities. Hence, an integrated programme of inventory, assessment and monitoring, in line with international practice, was initiated to form the basis of a future extended monitoring programme at both local and regional scales so that any mining-related impacts could be distinguished from those arising from other causes. This response in effect mirrored proposals put forward more than a decade earlier (Finlayson 1990) when the Supervising Scientist was not able, due to legislative reasons, to undertake such wide-ranging investigation.

As a first step, the ISP recommended an assessement and collation of existing information on aquatic and terrestrial ecosystems, at a landscape-catchment scale, in order to identify gaps in knowledge and to establish and, to prioritise the research elements needed to increase understanding of ecosystems processes such as recycling, biomagnification, and transfer of contaminants in food chains. As part of a full ecosystem risk assessment, the ISP also recommended that ‘surveys of the flora and fauna of the local area in and surrounding the Jabiluka lease and in the adjacent floodplains should be conducted, in consultation with traditional owners of the area and, where appropriate, the managers of the lease, paying particular attention to the potential for the occurrence of rare and endangered or endemic species and refugial or relictual habitats, together with a determination of the degree of threat to them’.

In response to these recommendations a series of landscape-wide projects that linked various threats and pressures (eg mining, invasive species, climate change & salinisation) to selected ecosystems in the Region, in particular wetlands, in order to determine appropriate risk management strategies, were initiated. Finlayson et al (2003) provides an introduction to some of these, while Lowry and Knox (2002) provide a landscape-scale map of the region.

3 Aims of the project

This project aims to collate and assess information on past and current research of waterbirds in the Alligator Rivers Region, and to determine its usefulness as a knowledge base for making decision about protecting the ecological integrity of the coastal and inland wetlands of the Region, noting the requirement to provide an assessment of key natural heritage values at a landscape-scale.

The specific objectives of the project are to:

- undertake a meta analysis of existing published & unpublished data to identify knowledge gaps;
- provide a basis for defining parameters used to monitor the use of the ARR wetlands by waterbirds;
- determine what factors are likely to influence, food and nesting resources of waterbirds and, hence, their distribution and abundance;
- develop conceptual models that incorporate basic ecological processes of wetland function and character and waterbird ecology;
- develope predictive waterbird-habitat dynamics model for use as a decision support tool in risk management of natural heritage values;
- investigate the potential of remote sensing to cost-effectively monitor & assess the condition of waterbird habitats over large, remote areas;
- provide scientific data to guide management decisions and actions and suggest management measures to maintain the values of wetlands;
- raise community awareness of the importance of waterbirds and their role in the ARR; and
- integrate this regional study with exsisting national and international waterbird monitoring programs.

In this report we outline the research framework used to address these objectives.

4 World Heritage Values

The concept of World Heritage Values is exceptional because of its universal application. World Heritage sites ‘belong’ to all the people of the world, unconditional of the territory in which they are located. Australia is rich in places of outstanding universal value and it has currently fifteen sites on the World Heritage List, including Kakadu National Park (http://whc.unesco.org/heritage.htm).

The Convention defines the kind of natural or cultural sites which can be considered for inscription on the World Heritage List and sets out duties of State Parties in identifying potential sites and their role in protecting and preserving them. By signing the Convention, each country pledges to conserve not only the World Heritage Sites situated on its territory, but also to protect its national heritage. If a country is not fulfilling its obligations under the Convention, it risks having its sites declared ‘in danger’ or deleted from the World Heritage List. Australia has played an important role in the practice and history of the Convention, and its involvement includes many pioneering developments. Australia has put in place domestic legislation specifically addressing its obligations under the World Heritage Convention.

To qualify for inscription on the World Heritage List, nominated properties must have values that are outstanding and universal (www.deh.gov.au/heritage/worldheritage/criteria.html).

Table 1 summarises the natural and cultural heritage criteria that apply to the listing of Kakadu National Park. All criteria in table 1 incorporate waterbirds in one way or other.

Table 1 Cultural and natural heritage criteria under which Kakadu National Park is listed as a World Heritage Site

Criteria	Comments
Cultural heritage	
Criterion (i): represents a unique artistic achievement, a masterpiece of creative genius	Art and Ceremonies
Criterion (vi): be directly or tangibly associated with events or living traditions, with ideas or with beliefs, or with artistic and literary works of outsanding universal significance. Equally important is the authenticity of the site and the way it is protected and managed.	Food resources, traditional hunting, traditional practices of environmental management (e.g. traditional burning)
Natural properties	
Criterion (ii): be outstanding examples representing significant ongoing ecological and biological processes in the evolution and development of terrestrial, fresh water, coastal and marine ecosystems and communities of plants and animals	Ecological value
Criterion (iii): contain superlative natural phenomena or areas of exceptional natural beauty and aesthetic importance	Tourism
Criterion (iv): contain the most important and significant natural habitats for *in situ* conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science and conservation	As represented by further listing under the Bonn Convention, Ramsar Convention, plus Jamba/Camba international agreements

4.1 Cultural Heritage values

Kakadu National Park and the Alligator Rivers Region, is a landscape of cultural, religious and social significance to local Aboriginal People. The Park contains one of the greatest concentrations of rock art in the world; approximately 5000 rock art sites have been recorded so far and it is thought that there are at least 10 000 sites in total (Press et al 1995 1995). A range of art forms and styles is found in Kakadu, such as rock paintings, rock engravings and designs in wax. These cultural expressions document the religious beliefs and traditional knowledge of Aboriginal culture. Subjects depicted include Dreamtime beings, totemic kin, mythological heroes and scenes of religious and ceremonial life. The paintings reflect the history of Aboriginal occupation of the landscape and the changes that occurred to the Aboriginal hunter-gatherer society as it came into contact with other cultures. Significant changes to landscape features and consequent changes in the availability of natural resources can be interpreted from the paintings and other artefacts. The paintings of the Pre-estuarine Period (dated from at least 20 000 years ago) include various macropods and human figures with boomerangs, suggesting a landscape similar to largely open savanna at that time. Following rise in sea level (from approx 8000 years ago) and the changing condition of the landscape associated with rain and floods, animals, and in particular fish, which flourished in the region with the emergence of estuarine conditions, started to be depicted (Chaloupka 1984, 1985). Waterbirds and freshwater fauna and flora species such as Jabirus, Sea Eagles, Magpie Geese and waterlilies are represented in the paintings of the 'Freshwater Period'(from 1500 years ago). Rock art is a repository of Traditional Ecological Knowledge (TEK), and still plays an important role in the cultural life of Aboriginal people today (fig 2).

Figure 2 Aboriginal rock art – Kakadu National Park

Several groups of Aboriginal people live in Kakadu National Park and within the Alligator Rivers Region, and continue to use the natural resources in a traditional manner. Many species of waterbirds are hunted and consumed as traditional food: Magpie Goose (*Anseranas semipalmata*), Wandering Whistling Duck (*Dendrocygna arcuata*), Plumed Whistling Duck (*Dendrocygna eytoni*) and Green Pygmy Goose (*Nettapus pulchellus*). Aboriginal people continue to be very familiar with the life history and the ecology of these species, exploiting the resources according to the seasonal cycle and maintaining a diversity of habitat conditions for species with differing requirements through traditional management practices (eg fire management) linked, where appropriate, with more contemporary practices (fig 3a–b).

Figure 3 Left: Traditional food items, eg Magpie Goose (*Anseranas semipalmata*). Right: Fire management under contemporary management regimes.

4.2 Natural Heritage values

In comparison with the rest of the Australia continent, the environment of north Australia is considered to be less degraded and includes extensive and, relative to many areas elsewhere, unmodified vegetation cover and a largely intact fauna.

Despite being subject to pressure from feral animals and weeds the coastal floodplains and the alluvial floodplains of Kakadu National Park and the surrounding Alligator Rivers Region have immense ecological, cultural and scenic significance (Christian & Aldrick 1977, Brennan 1986, Ovington 1986, Miles 1986, Dugan 1993). This significance is well illustrated by the value attributed to the aggregation of waterbirds that abound across the floodplain habitats (Morton et al 1990a,b, 1991).

Kakadu National Park is world renowened for its diverse bird life. More than 280 species have been recorded – equivalent to about one third of Australia's avifauna. Waterbirds are a major touristic attraction, in particular some iconic species such as the Jabiru (*Ephippiorhynchus asiaticus*), Brolga (*Grus rubicunda*), White-bellied Sea Eagle (*Haliaeetus leucogaster*) and the Magpie Goose (*Anseranas semipalmata*). The high diversity and abundance of waterbirds species, especially migratory species, and the high natural values of the ecosystems are one of the reasons for Kakadu National Park being listed as a World Heritage area.

5 Wetland Convention values

In accordance with the Convention on Wetlands (www.ramsar.org) waterbirds are broadly defined as 'birds ecologically dependent on wetlands' and include traditionally recognised groups of birds known as wildfowl, waterfowl and shorebirds. Table 2 lists the twenty families of waterbirds accepted under the Ramsar definition and included in the Asia-Pacific Migratory Waterbird Strategy (2001–2005) and found in Kakadu National Park and in the Alligator Rivers Region. Appendix 1 lists all species of waterbirds, seabirds and shorebirds recorded in the Alligator Rivers Region and in Kakadu National Park.

Table 2 Waterbirds families listed in the Asia-Pacific Migratory Waterbird Strategy 2001–2005 and found in Kakadu National Park and the Alligator Rivers Region

Taxonomic family	Common name
Podicipedidae	Grebes
Phalacrocoracidae	Cormorants
Pelecanidae	Pelicans
Ardeidae	Herons, Egrets and Bitterns
Ciconidae	Storks
Threskiornithidae	Ibises and Spoonbills
Anatidae	Swans, Geese and Ducks
Gruidae	Cranes
Rallidae	Rails, Gallinules and Coots
Jacanidae	Jacanas
Haematopodidae	Oystercatchers
Recurvirostridae	Stilts and Avocet
Glareolidae	Pratincoles
Chradriidae	Plovers
Scolopacidae	Sandpipers
Laridae	Gulls, Terns and Skimmers

This project will consider all species, of both inland and coastal wetlands, included in the taxonomic groups in table 2. This includes shorebirds (waders) that are defined according to the species listings in Lane (1987) and Watkins (1993). In addition to these groups there are other species that are dependent on wetlands, such as the kingfishers and passerines. Although these birds would benefit from efforts undertaken to conserve waterbirds, they are not the focus of this project.

The importance of the Alligator Rivers Region to waterbirds has been extensively documented over many years (Frith 1961, Frith & Davies 1961, Bamford 1988, 1990, Bayliss & Yeomans 1990, Morton et al 1990a,b, Chatto 2000a, 2000b, 2001, 2003, Saalfeld 1990, Tulloch et al 1988, Whitehead et al 1987, Whitehead et al 1992, Whitehead & Dawson 2000). The wetlands of Kakadu and the Alligator Rivers Region support waterbirds in numbers of international and national significance, and the floodplains of Kakadu provide important refuge areas critical to the conservation of waterbirds throughout the Top End of the Northern Territory (Morton et al 1991). During the dry season (August–October), the floodplains are used intensively by up to 2 million waterbirds, including particularly large concentrations of Magpie Geese (*Anseranas semipalmata*) and Wandering Whistling Duck (*Dendrocygna arcuata*). The mosaic of contiguous wetlands comprising the catchments of the East Alligator River and South Alligator River recived the Ramsar designation on 12 June 1980 (Kakadu National Park Stage 1), and subsequently the Magela Creek floodplain, the lower South Alligator River floodplain, the entire West Alligator River system, and all of the Wildman River were listed under the convention on 15 September 1989 (Kakadu National Park – stage 2), on 12 June 1980 further individual wetlands along these rivers were included (Kakadu National Park – stage 3):
(www.wetlands.org/RDB/Ramsar_Dir/Australia/AU002D02.htm)
(www.ramsar.org/lib_dir_2_5.htm).

Of the 107 species of waterbirds(seabirds included) reported to occur in the Alligator Rivers Region (Morton et al 1990a,b, Press et al 1995, Chatto 2003), 54 are shorebirds of which 33 are migratory. Importantly, waterbirds of the ARR have a high cultural significance to Aboriginal people. An easily sustained level of hunting and gathering by Aboriginal people living in and around the region takes place in accordance with long-standing tradition. Other key uses of the wetlands include conservation and tourism (Brennan et al 1992) (www.ramsar.org/lib_dir_2_5.htm).

6 Alligator Rivers Region wetlands

The Ramsar Wetlands Convention defines wetlands as ‘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 1.1) and ‘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’(Article 1.2). Wetlands in the Alligator Rivers Region encompass extensive waterbird and shorebird habitats with approximately 244 km of coastline (including offshore islands such as Field Island), and 3466 km^2 of wetlands, of which 3014 km^2 are classed as ‘swamp’ or ‘land subject to inundation’ (Lowry & Finlayson 2004).

Finlayson et al (1988) classified the wetlands of the Alligator Rivers Region into: coastal plains and riverine mangrove fringes; salt flats; freshwater seasonally inundated floodplains; and billabongs.

6.1 Coastal plains and riverine mangrove fringes

Large meandering rivers form the upper reaches of the coastal floodplains of the Alligator Rivers Region and then grade into the saline mud-flats near the coast (East 1996, Finlayson & Woodroffe 1996, Lowry & Knox 2002). The coastal areas are dominated by saline mudflats and mangrove forests. Examples of this landscape can be found on the lower reaches of the South Alligator, East Alligator and West Alligator rivers.

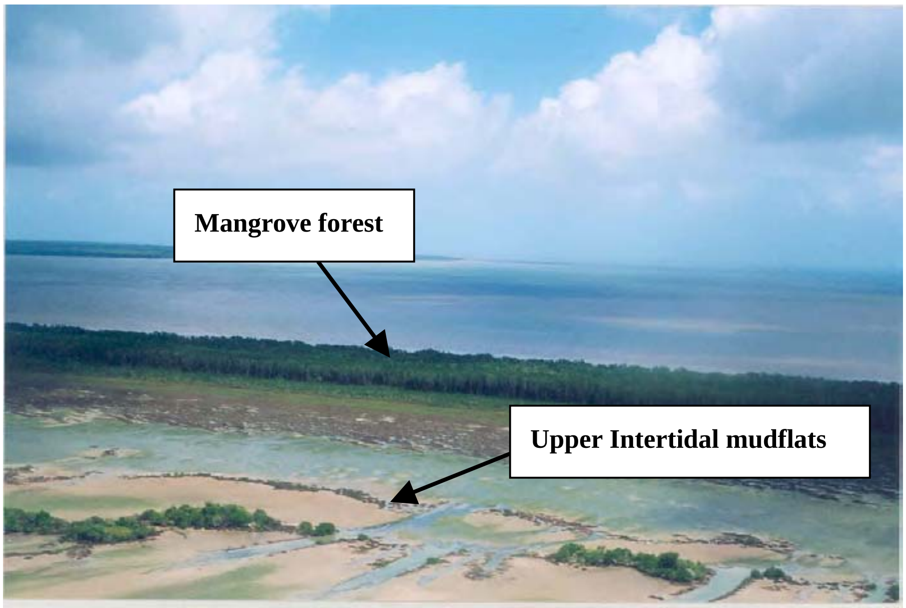

Figure 4 Alligator Rivers Region – South Alligator – coastal plains

Tidal processes influence this landscape, distinguishing it from the freshwater wetlands of the alluvial landscape including rivers, billabongs and seasonally inundated freshwater flood-plains. A belt of mangrove forests is found along the shoreline and extends inland along the todally influenced reaches of the river (fig 4). While water salinity is a major factor determining the distribution of mangrove species along the course of tropical rivers the factors that influence mangrove distribution in the Alligator Rivers Region have not been specifically described (Bunt et al 1982, Wells 1984, Ball 1988, Ball & Pidsley 1988). The distribution and zonation patterns of mangrove species in the Alligator Rivers Region has been described by several authors (Finlayson & Woodroffe 1996, East 1996). Two intertidal saline mudflats areas extend in front and behind the belt of mangrove forest (Woodroffe et al 1986). The lower intertidal mud area extend seawards and the upper intertidal saline mudflat area , partly covered during spring tides, extends behind the mangrove forest (figure 5).

The lower intertidal mud and the upper intertidal saline mudflats of the costal plains are used by migratory shorebirds. Every year millions of waders migrate between their breeding grounds in the Paleartic and their non-breeding ground in the tropics and Australasia (Parish 1987, Watkins 1993). Extensive aerial surveys of the coastline and adjacent saline wetlands of the Top End, conducted in the last 15 years by Chatto (2003), have demonstrated the significance of shorebird habitat across the Top End. Chatto (2000a, 2003) reported that numerous roosts of shorebirds, containing 2000 or more birds, were spread across the coastline of the Alligator Rivers Region. He recorded almost 9000 shorebirds at Finke Bay in a single aerial survey in September 1993 and around 12 500 individuals, during two ground surveys in late April 1992 and late March 1992 , along the coast between the South Alligator River and Minimini Creek.

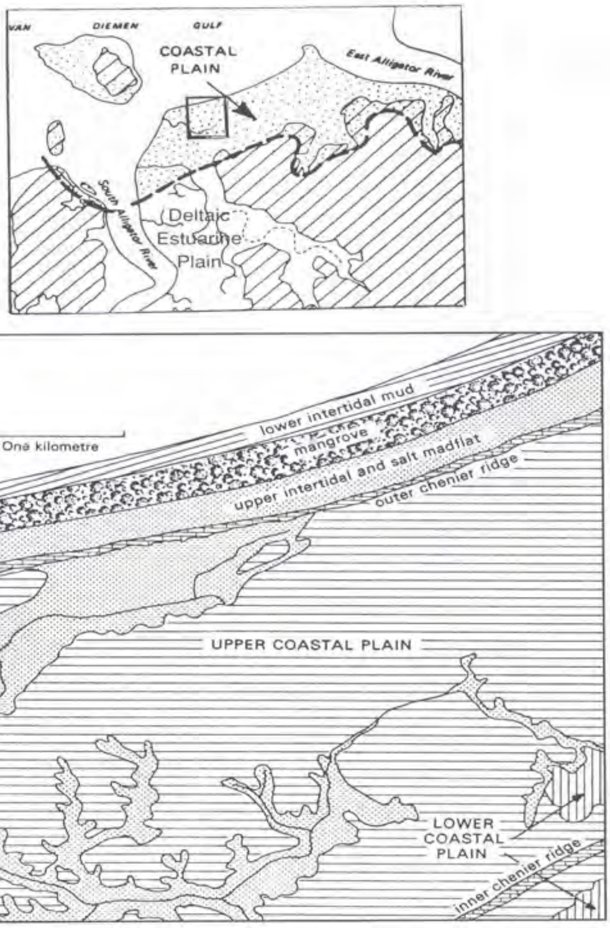

Figure 5 Morphologic provinces of the estuarine South Alligator River floodplain (adapted from Woodroffe et al 1986)

The mangroves fringing the river banks provide suitable habitat for nesting colonial waterbirds (fig 6). Along the mangroves of the East Alligator and South Alligator rivers, including its tributary Coopers Creek, large multi-species colonies of Intermediate Egret (*Egretta intermedia*), Cattle Egret (*Ardea ibis*), Great Egret (*Ardea alba*), Little Egret (*Ardea garzetta*), Pied Heron (*Ardea picata*), Little Pied Cormorant (*Phalacrocorax melanoleucos*), Little Black Cormorant (*Phalacrocorax sulcirostris*) and Australian White Ibis (*Threskiornis molucca*) were recorded between 1990 and 1999 (Chatto 2000b).

Figure 6 Mangroves fringing the rivers banks, South Alligator coastal floodplain

6.2 Inland freshwater floodplains and billabongs

Seasonally inundated floodplains of Holocene organic clay sediments occur in the lower reaches of the main rivers and their major tributaries, and merge with the upstream flood plains and tidal flats of the estuaries (fig 7). Floodplains include both treeless grassy plains and thickly wooded alluvial flats. The latter are covered intermittently by overbank floods and may be waterlogged for much of the wet season. They cover extensive areas, for example the floodplain at the confluence of the South Alligator River, Buffalo Creek and Coirwong Creek has an area of about 80 km^2 (East 1996).

Figure 7 Flood-plains of the Magela Creek during the wet season (Feb.2003)

Billabongs are part of the floodplain river ecosystem and are strictly defined as oxbow lakes (Bayly & Williams 1977). In the Alligator Rivers Region region, however, this definition is not used; colloquially, all waterholes and lagoons are generically referred to as billabongs (Finalyson et al 1989). Some billabongs retain water all the year round whilst others dry out (fig 8).

Figure 8 Malabanbandji billabong in the wet season (left) and Bupa billabong in the dry season in Kakadu National Park (right)

The extremes of flood and drought of the floodplains and billabongs produce a diverse flora with characteristic wet and dry season plant communities. In the wet season the floodplains are covered by water and include plant communities such as *Oryza* grassland, *Hymenachne* grassland, *Pseudoraphis* grassland, *Hymenachne-Eleocharis* swamp, mixed grassland and sedgeland, and *Eleocharis* sedgeland (Finlayson et al 1989, 1990, Finlayson & Woodroffe

1996). During the dry season these areas may dry out and by the end of the dry season little aquatic vegetation is present. Use of the floodplains by waterbirds varies seasonally and some species move between floodplains across the region to more suitable habitats for breeding, roosting and feeding (fig 9).

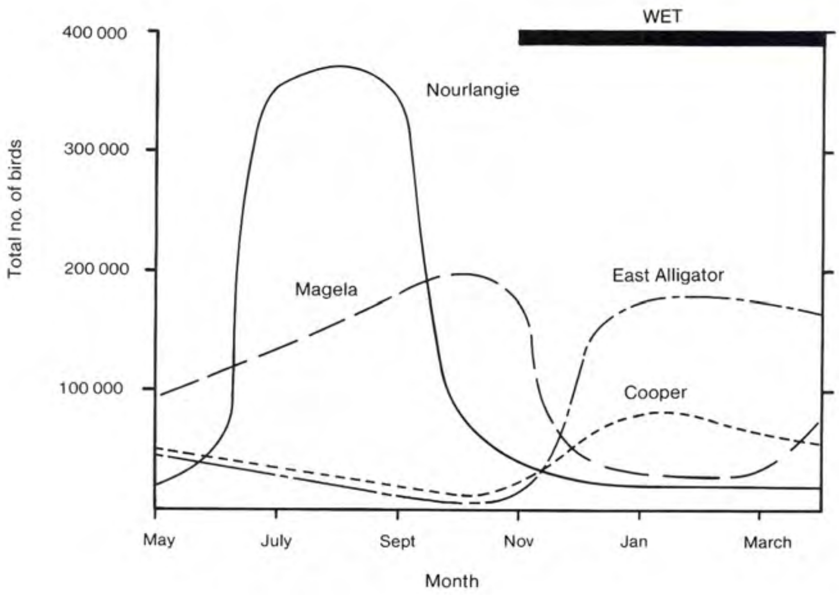

Figure 9 Diagrammatic representation of seasonal use by waterbirds of four floodplains (Nourlangie, Magela, East Alligator and Cooper Creek) of the Alligator Rivers Region, as determined by aerial surveys (from Morton et al 1984)

The diets of aquatic herbivourous species, such as the Magpie Goose, Wandering Whistling Duck (*Dendrocygna arcuata*), Plumed Whistling Duck (*Dendrocygna eytoni*), and the Green Pygmy Goose (*Nettapus pulchellus*) are linked to the phenological state of the floodplain plants (Morton et al 1990a,b, Finlayson et al 1990a). As the floodplain waters recede, during the dry season, a number of waterfowl species from southern Australia, such as Hardhead (*Aythya australis*), Grey Teal (*Anas gracilis*), Pink-eared Duck (*Malacorhynchus membranaceus*) arrive. The grasslands of the Alligator Rivers Region host migratory species such as the Little Curlew (*Numenius minutus*) (Garnett & Minton 1985, Bamford 1988, 1990, Morton et al 1991, Schulz 1989). The Little Curlew, a species that breeds in Siberia and over-winters in Australia, arrives at the inland wetlands of the Alligator Rivers Region in the latter part of September. They build up in numbers until the onset of the wet season, usually December, at which time they move to the sub-coastal floodplains of the Karumba region (Qld) and around Broome, and to the grasslands of the Barkly Tablelands (Bamford 1990). Morton et al (1991) estimated approximately 300 000 Little Curlew staging through the inland wetlands in Kakadu during October in the early 1980s, and Bamford (1990) estimated 50 000 Little Curlew in the Kakadu region in the late dry seasons of 1987–1989. Kakadu is nationally important for the Little Curlew (*Numenius phaeopus*) between September and November. The highest count, reported by Bamford (1988), of 21 900 individuals in October/November 1987 represented 45 % of the Australian total given by Lane (1987) and more than 1% of the minimum population estimates for the Little Curlew population in the East Asian-Australasian Flyway:
(www.deh.gov.au/water/wetlands/mwp/guidelines/population.html).

7 Waterbirds as indicators of wetland health

7.1 Development of conceptual models

The wetlands of the ARR and, in general, the wetlands of northern Australia, are considered to be far less disturbed than those elsewhere in Australia (Storrs & Finlayson 1998, Finlayson et al 1998). However, general analyses and reviews over the past two decades have identified a suite of pressures that are, or will affect the ecological condition of these wetlands and the biodiversity that they support. Potential biophysical pressures upon wetlands and, in particular, waterbird habitats include:

- loss of extent and diversity of habitat due to weeds such as *Mimosa pigra* (Walden et al 2004), and introduced grasses such as Olive Hymenachne (*Hymenachne amplexicaulis*), Para grass (*Brachiaria mutica*) and Salvinia *(Salvinia molesta)* (Finlayson et al 1997a);
- loss of freshwater habitat due to rising sea level from climate change and consequent saltwater intrusion (Bayliss et al 1997, Eliot et al 1999, Waterman et al 2000);
- damage to micro and macro-scale habitats caused by feral animals such as pigs and buffalos (Skeat et al 1996, East 1996);
- and the yet unknown potential impacts of cane toads (van Dam et al 2002).

In order to conserve and maintain the ecological integrity of the coastal and inland wetlands of the Alligator Rivers Region, and maintain the natural heritage values of Kakadu National Park in particular, it is essential to identify the processes and the dynamics that provide and maintain the ecological character (sensu www.ramsar.org/key_res_vi.1.htm) of these ecosystems. As waterbirds are a key component of tropical wetlands they have the potential to be used as indicators of the ecological character, or more specifically, provide an index of wetland 'health'.

Understanding the dynamics of wetland habitats, and how they may influence the biodiversity of waterbirds has been a challenge facing scientists and wetland managers of northern Australia, both in terms of conservation and management practices, for many years. Despite the valuable knowledge that has been accumulated, the levels of uncertainty are still very high in terms of how these complex ecosystems function. In order to close some of the gaps in our knowledge, conceptual models that incorporate key structural components and system drivers, can be used to elaborate the context and scope of the processes that affect the ecological integrity of these systems (Karr 1991).

For a better understanding of the inherent complexity of ecological relationships, the variability of living organisms, and the apparently unpredictable effects of human intervention in the natural system, an explicit and logical representation of the underlying relationships is required (Jeffers 1982). Conceptual models can be used to represent these relationships. The purpose of a conceptual model is to provide a formal structure so that:

- knowledge of the system can be expressed in a concise and easily interpretable manner;
- gaps in knowledge of individual components of the systems, and of system functions as a whole, can be identified;
- attention is focussed on the whole system and the driving forces, as well as the individual components;
- predictions can be made in term of vulnerability of the system and how the different components respond to environmental perturbations; and
- management decisions can be taken to maintain the ecological integrity of the system.

7.2 Inventory and gap analysis: assessing historical information

Reliable knowledge is the basic resource on which all decisions concerning the conservation, management and wise use of wildlife and wetlands in general should be made. Much effort has been devoted to determining the occurrence, distribution and abundance of waterbirds in the Alligator Rivers Region (Bamford 1988, 1990, Morton et al 1990a,b, 1991,1993 a,b, Bayliss & Yeomans 1990) and the surrounding 'Top End' (Bayliss & Yeomans 1990, Saalfeld 1990, Chatto 2000b, 2001,2003). This information has provided an inventory of the waterbirds present in the Region as well as identified various relationships between particular species and habitats. Much of the past effort has focussed on surveys as a basis for further analysis.

The methods used in these surveys included:

1 Standardised sample counts via systematic aerial surveys: predetermined transect lines were flown using fix-winged aircrafts at regular intervals across different seasons and years. Seasonal distribution and relative abundance of waterbirds were then determined.

2 Ground count surveys: total counts of birds observed at selected sites. Seasonal distribution and relative abundance of waterbirds were then determined.

3 Opportunistic counts via aerial surveys: surveys in which the main aim was to collect general information on wildlife (waterbirds, shorebirds, turtles, dugongs) distribution and occurrence across the Top End. All records are point records rather than records relating to an area. Estimates of densities or comparison across seasons or years is not possible with this data. Nevertheless, these surveys enabled the identification of sites of high waterbird abundance and diversity.

4 Mapping colonial nesting areas: eg, censuses of the distribution of Magpie Geese nest carried out at different scales, hence indices of habitat suitability can be determined.

Despite the fact that these surveys initially established reliable baseline data sets for many waterbird species, and sufficient temporal and spatial data, much remain to be investigated at the level of:

- ecological drivers influencing the patterns of distribution at an individual/community level;
- ecological factors affecting the functioning of waterbirds habitat;
- modelling of population dynamics; and
- assessment of vulnerability of waterbirds habitat and consequent evaluation of management actions to maintain the values of sites of conservation importance, with respect to World Heritage and Ramsar values particularly.

7.3 Identification of ecological drivers

The use of ecological conceptual models from individuals to populations and communities is a widely used tool that has not been greatly applied in the Alligator Rivers Region. Such models can provide valuable insights into the factors which affect the fecundity and survival of individual animals and have consequences for populations as a whole (Choquenot & Dexter 1996). Factors that can influence the distribution and abundance of individual birds and hence the population as a whole include:

- Food supply
- Weather

- Habitat
- Predators and pathogens
- Nesting sites availability
- Interspecific and intraspecific competition

Understanding 'cause-and-effect' relationships between these factors and the distribution and abundance of birds is a complex task, as interactions between them often make it difficult to identify which is/are the relevant drivers. By using ecological conceptual models we aim to identify, simplify and explain these relationships.

Using information available on diet and individual body condition, relationships at the level of individual species will be explored using the ecological conceptual model shown in fig 10.

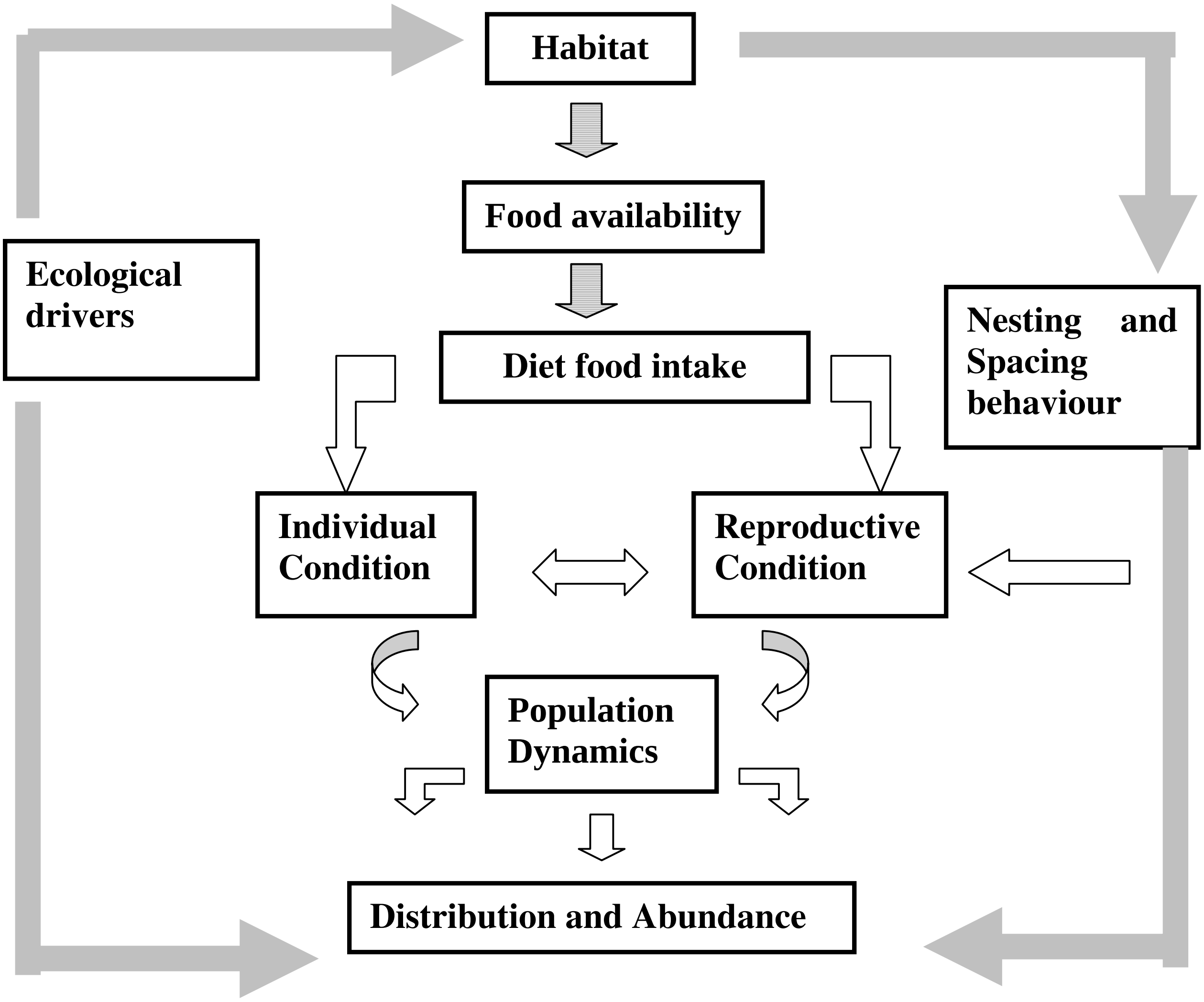

Figure 10 Ecological conceptual model describing the relationships at the level of individual species

This model specifically links habitat features with eco-phisiological and behavioural traits of individuals to populations as a basis for determining the effect of selected ecological drivers, such as rainfall patterns, events of flooding and droughts etc. This will enable the derivation of hypoteses about the influence of ecological drivers on individuals and populations, and hence the values associated with waterbirds in the Region. It is anticipated that the derived hypotheses will guide the direction of future research directions, as well provide a basis for wider communication of the critical links between ecological drivers and waterbirds.

7.4 Multivariate analysis and ecological guilds

Community ecology and environmental science are multivariate in character (many species, multiple environmental variables). Hence, the use of multivariate analysis techniques enable ecologists to investigate patterns in community structure that are often not readily apparent from simple exploration of the data by traditional statistical methods.

Previous studies (Morton et al 1991) have confirmed that there is evidence of regular movement of birds between floodplains of the Alligator Rivers Region. Localised food availability and changes in water levels and flooding regimes probably affect usage of the floodplains by waterbirds and account for many of the short-term changes in local populations. Using multivariate analysis we aim to investigate in more detail the patterns of waterbirds usage of the different floodplains in the Alligator Rivers Region, and to identify similarities at the landscape scale between floodplains. We will also investigate whether or not waterbirds can be grouped into ecological guilds (Jaksic 1981), or groups of species, that exhibit the same pattern of distribution across the floodplains, and if similarities can be explained by knowledge of a subset of species (key indicator species). In this way we anticipate determining whether or not it is possible to forecast the types of birds that are likely to respond in similar ways to environmental perturbation.

The analysis will include:

- *Discriminating sites*: investigate whether or not there are similar patterns of waterbirds usage between floodplains.
- *Representing communities*: investigate whether or not the patterns can be explained by a subset of species that as such can be used as representative and as key indicator species.
- *Linking multivariate biotic patterns to environmental variables*: investigate if community differences associated with different floodplains can be linked to specific weather events, abiotic site conditions and so on.

The multivariate analysis will provide information that supports a better understanding of the dynamics that regulate waterbirds and their habitats within the Alligator Rivers Region. Furthermore, the investigation and introduction of the predictive aspect, by using key indicator species, will provide a useful tool for future monitoring and management practices aimed at maintaining the World Heritage and Ramsar values of the waterbirds in the Region. In this manner factors that influence waterbirds distribution across the floodplain will be assessed, hypothesis raised, and key factors incorporated into the framework.

8 Monitoring and proactive management implications

The overall goal of this project is to assess the World Heritage and Ramsar values and maintain and improve the conservation of waterbirds and their habitats in the Alligator Rivers Region including Kakadu National Park. As noted by Finlayson et al (2002) the collection and /or collation of core information for wetland management is an essential step for later specific assessment and monitoring activities. Inventory, assessment and monitoring should be considered as inter-linked processes such as that adopted in the framework proposed by the Ramsar Convention (www.ramsar.org/key_res_viii_06_e.pdf). The framework is intended as a tool to guide ecosystem management well into the future by ensuring that key information collection, inventory, assessment and monitoring procedures result in information that can be readily accessed and used. Based on definition provided in Finlayson et al (2002) the framework includes the following three separate elements:

- *Inventory*: the collection of core information, including the provision of an information base for specific assessment and monitoring activities.
- *Assessment*: the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities.
- *Monitoring*: collection of specific information for management purposes in response to hypotheses derived from assessment activities, and the use of these monitoring results for implementing management.

The framework in effects provides a structural link to support monitoring and lessen the possibility that past problems with monitoring programs, as identified by Finlayson and Mitchell (1999), will be repeated. The integrated framework, termed WIAM (Wetland Inventory Assessment System) (Humphrey et al 2002), can be expanded and linked with specific research, modelling, and consultation in communication activities (Finlayson et al 2003).

Long-term monitoring programs can be established in order to provide guidance or maintaining the ecological characteristics of the wetlands in the Alligator Rivers Region and Kakadu National Park. Monitoring of waterbirds is essential in order to detect and to provide answers about changes in waterbird distribution and abundance, and of the ecological condition of their habitats. It is vital for understanding the underlying causes for any declines in populations, and to prevent key components of the biodiversity of wetland habitats from being degraded or lost (Asia-Pacific migratory waterbird conservation strategy 1996-2000).

8.1 Conservation measures at different scales and monitoring programs

Given the mobile nature of waterbirds species, in particular migratory species, there is a need not only for reasearch at different scales, but also for conservation measures and legislation at different scales (global, national, regional, local). Around the globe, waterbirds have been shown to be a powerful and efficient vehicle to focus attention and mobilise action for conservation and sustainable use of wetlands and their biota at local, national and international levels (www.wetlands.org/IWC/WPEnote.htm).

8.1.1 Global scale

There are four international conventions and several bilateral agreements that are relevant to the conservation of migratory waterbirds and their habitats in the Asia Pacific region:

- *Ramsar Convention*: Convention on Wetlands of International Importance, especially for Waterbird Habitats (www.ramsar.org).
- *Convention on Migratory Species*: Convention on the Conservation of Migratory Species of Wild Animals (www.wcmc.org.uk/cms).
- *Convention on Biological Diversity* (www.biodiv.org).
- *CITES Convention*: convention on International Trade in Endangered Species of Wild Fauna and Flora (www.cites.org).

Australia is a signatory to two international bilateral agreements that specifically protect migratory birds and their habitats:

- JAMBA: the Japan-Australian Migratory Bird Agreement (www.deh.gov.au/water/wetlands/mwp).

- CAMBA: the China-Australia Bird Agreement (www.deh.gov.au/water/wetlands/mwp).

These agreements recognise the importance of conserving migratory birds and their habitats. Under the bilateral agreements, species of migratory birds that occur in Australia, Japan and China are listed. The birds listed under JAMBA and CAMBA are also protected under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Commonwealth) and the Convention on Migratory Species.

Additionally, Australia is involved in several international initiatives that deal with the conservation of waterbirds and their habitat:

- The Asia-Pacific Migratory Waterbird Conservation Strategy: developed in 1994, at a workshop involving 16 nations held in Kushiro, Japan, to discuss the conservation of migratory waterbirds in East Asia and Australasia. The workshop was held to prepare a strategy that identified the major issues for the conservation of migratory waterbirds in the region, outlined the range of priorities for action, and set out a time table for implementation and evaluation. The result was the Asia-Pacific Migratory Waterbird Conservation Strategy 1996–2000 which was produced by Wetland International and the International Waterfowl and Wetlands Research Bureau-Japan Committee (Asia-Pacific migratory waterbird conservation strategy 1996-2000). The development and subsequent implementation of the strategy, and its second iteration for 2001–2005, has recived strong support from the Ministry of the Environment, Japan, and the Commonwealth Government of Australia through the Natural Heritage Trust (Ferris & Madon 2003) (www.wetlands.org/IWC/awc/waterbirdstrategy/default.htm).
- The International Waterbird Census (IWC): a project initiated by IWRB (a predecessor of Wetlands International) in 1967. The IWC was first established in Europe and a few countries in Asia and Africa and in 1987 extended with the Asian Waterbird census. Now, it covers 100 countries in five continents, and over 10 000 mainly voluntary waterbird counters participate. Information derived from the IWC is used as a basis for strategic input to other activities such as the Red Data Book of IUCN, and BirdLife International's Important Bird Areas (IBA) programme. It also provides valuable information for Waterbird Species Action Plans, such as those developed for the European Commission and European Union, and data for many waterbird population estimates. The third edition of *Waterbird Population Estimates* recently published by Wetlands International is a global analysis derived from the data collected in the IWC (Delany & Scott 2002) (www.wetlands.org/IWC/WPEnote.htm).

8.1.2 National scale

Several national schemes for monitoring waterbirds are coordinated at a national level across the world (such as the Asian Waterbird Census (AWC)). In Australia many management administrative initiatives and research are being undertaken at a State level. However Australia lacks a nationally coordinated waterbird monitoring program. Research at regional and local scale has been of great value in building the capacity of institutions to undertake their own regional assessments of the status of waterbirds conservation. However, many local initiatives only present snapshots in time and are very difficult to integrate, compare and interpret. The quality assurance of data and consistency of collection of data techniques are obviously a great constraint to the development of a useful monitoring program at a national level.

A workshop, held in Adelaide, 3–4 April 2003, was convened by the Department of Environment and Heritage under the auspices of the Wetlands and Waterbirds NRM Taskforce, in order to discuss a 'National Approach to Waterbird Population Information' (Ferris 2003). The workshop was attended by representative of State/Territory conservation agencies, research and tertiary education institutions and non-government conservation organisations.

The workshop had three objectives:

1. to establish the key population, habitat and threat information required for management of waterbird populations in Australia;
2. to explore methods available to gather the information and describe the issues associated with each method; and
3. to determine cooperative approaches to meeting the information needs and agree on the best way to initiate an appropriate program of activities.

The workshop explored the requirements to manage informationm on waterbird populations and determined that there was much commonality across jurisdictions. The key needs identified included:

- identification and management of important wetlands and wetlands systems;
- effective management of waterbird species, particularly threatened and game species;
- measuring trends in condition and abundance of important wetlands and waterbirds species;
- quantifying the impact of threats (particularly at a catchment or regional scale) to wetlands and waterbird habitats in particular; and
- meeting international and legislative obligations

The workshop then discussed the way forward and the approaches available. The main outcomes are listed below:

1. Support for analysis of the first 20 years of data from the Eastern Australia Aerial Surveys of waterbirds, particularly in respect to trends in abundance and diversity of waterbirds on key wetlands.
2. Recognition of the value of the long-term data set collected through the annual Eastern Australia Aerial Survey and support for continuation of the survey in its current form, while acknowledging that there are some historical shortcomings in the design and issues with data management which need to be resolved.
3. Support for the concept of a new national program, which was titled the National Audit of Waterbirds and Shorebirds.

The workshop agreed that the audit:

- should use a multifaceted approach, with aerial survey and ground-based techniques being used by professional and amateur staff, to undertake a simultaneous count of key wetlands across Australia;
- would cover all species of waterbirds including migratory shorebirds;
- should be planned as an ongoing program, particularly with respect to seeking independent statistical advice, but would be run as a one-off trial to test financial and other resources required (there was agreement that a one-off ‘national snapshot’ would add considerably to our knowledge of waterbird populations Australia); and
- should be designed and planned over the coming 12 months and conducted in 2004/2005;

- should be coordinated by a steering committee, and the workshop group should be maintained as a Reference Group; and
- should involve government agencies who required its products.

The information available from the project proposed for assessing the World Heritage and Ramsar values of waterbirds in the Alligator Rivers Region' will provide input any such national program.

8.1.3 Local scale: site specific (Magela Wetlands)

Research carried out on waterbirds in the Alligator Rivers Region in the early 80s mainly focussed on addressing the possible impact of the mining activities on the Magela floodplain system. Baseline information was collected on the pre-mining levels of several heavy metals in feathers, muscles and livers of 22 species of waterbirds that occur commonly on the Magela creek floodplain (Brennan et al 1992). Seasonal patterns of usage of wetlands downstream of major uranium deposists were identified by the study of Morton et al 1984. These previous studies were mainly descriptive. We now intend to introduce a predictive capacity by attempting detailed analysis of individual species (conceptual models) and of ecological groupings of waterbirds and their habitat selection.We will focus on individual groups of birds that are likely to respond in similar ways to environmental perturbations. The outcomes will represent the baseline information requested by the ISP, on behalf of the World Heritage Committee, on which to base predictive modelling, risk assessment and monitoring programmes in order to maintain the World Heritage Values of Waterbirds and their habitat in Kakadu National Park, and in general in the Alligator Rivers Region.

9 Communication strategy

A comprehensive assessment of the World Heritage and Ramsar Convention values of waterbird species and their habitats should be undertaken in conjuction with inputs and participation from the local communities who utilise and own the wetlands (Finlayson et al 1997b). The ecological values of waterbirds and their habitats cannot be separated from the social values that they represent. Human interaction with the environment is diverse and there are many specific values, each appreciated by different individuals and stakeholders groups (Stuip et al 2002). For example, to one stakeholder a wetland may represent a development opportunity, while to others it is an essential resource providing food and supporting cultural values. Across the Top End of the Northern Territory, including Kakadu National Park and the Alligator Rivers Region land tenure and wetland use varies. Uses include agriculture, grazing, mining, traditional hunting, conservation, tourism and recreation. Land tenure varies from leasehold under the Northern Territory jurisdiction to Aboriginal land under Commonwealth jurisdiction in Kakadu National Park and Aboriginal inalienable freehold in Arnhem Land (Finlayson et al 1997b). Different perceptions of the wetlands values interact in Kakadu and in the Alligator Rivers Region. Stakeholders groups include: Aboriginal Traditional Owners (TOs), other resident Aboriginal people, Indigenous associations (NLC and others), other non Indigenous people, Commonwealth and Northern Territory agencies, the mining company (ERA) and the general public (including tourists).

The communication strategy for this project in conjunction with the others already initiated in the Alligator Rivers Region aims to:

- improve community understanding by reporting timely and appropriately results and research outcomes;
- acknowledge existing knowledge, in particular Traditional Ecological Knowledge, by working in collaboration with Traditional Owners and other indigenous people; and
- involve local communities in establishing management priorities and conservation management for waterbirds and their habitats.

This will include briefings at local and wider scale about the outcomes of the project, participation at events aimed at raising awareness of the importance of waterbirds and their habitat in the Alligator Rivers Region and adjacent areas, in particular other regions of the Top End where waterbirds move once conditions become habitat unsuitable in the Alligator Rivers Region (ie seasonally movements of resident and migratory species), the production of communication outputs, such as brochure or fact-sheets targeted at different audiences (scientists, general public, indigenous people). Examples of the activities that can contribute to the communication goals are outlined in Finlayson et al (2000) and could involve linkages with national programs such as these held for World Wetland Day, 2nd of February (www.deh.gov.au/water/wetlands/publications/wa12/world.html), and World Environment Day, 5th of June (www.unep.org/wed/2004/), and support further development and implementation of international strategies such as the Asia-Pacific Migratory Waterbird Conservation Strategy (www.wetlands.org/IWC/awc/waterbirdstrategy/Intro.htm).

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Appendix 1 List of waterbirds, seabirds and shorebirds recorded in the Alligator Rivers Region and Kakadu

Common name	Scientific name	Jamba	Camba
Magpie Goose	*Anseranas semipalmata*		
Wandering Whistling-duck	*Dendrocygna arcuata*		
Plumed Whistling -duck	*Dendrocygna eytoni*		
Radjah Shelduck	*Tadorna radjah*		
Green Pygmy Goose	*Nettapus pulchellus*		
Pacific Black Duck	*Anas superciliosa*		
Grey Teal	*Anas gracilis*		
Garganey	*Anas querquedula*	X	X
Pink-eared Duck	*Malacorhynchus membranaceus*		
Haedhead	*Aythya australis*		
Australasian Grebe	*Tachybaptus novaehollandiae*		
Hoary-headed Grebe	*Poliochephalus poliocephalus*		
Darter	*Anhinga melanogaster*		
Little Pied Cormorant	*Phalacrocorax melanoleucos*		
Pied Cormorant	*Phalacrocorax varius*		
Little Black Cormorant	*Phalacrocorax sulcirostris*		
Great Cormorant	*Phalacrocorax carbo*		
Australian Pelican	*Pelecanus conspicillatus*		
Great Frigatebird	*Fregata minor*	X	X
Lesser Frigatebird	*Fregata ariel*	X	X
White-faced Heron	*Egretta novaehollandiae*		
Little Egret	*Egretta garzetta*		
Eastern Reef Egret	*Egretta sacra*		X
White-necked Heron	*Ardea Pacifica*		
Great-billed Heron	*Ardea sumatrana*		
Pied Heron	*Ardea picata*		
Great Egret	*Ardea alba*	X	X
Intermediate Egret	*Ardea intermedia*		
Cattle egret	*Ardea ibis*	X	X
Striated Heron	*Butorides striatus*		
Nankeen-night Heron	*Nycticorax caledonicus*		
Black bittern	*Ixobrychus flavicollis*		
Australia white Ibis	*Threskiornis molucca*		
Straw-necked Ibis	*Threskiornis spinicollis*		
Glossy Ibis	*Plegadis falcinellus*		X
Royal Spoonbill	*Platalea regia*		
Yellow-billed Spoonbill	*Platalea flavipes*		

Common name	Scientific name	Jamba	Camba
Black-necked Stork	*Ephippiorhyncus asiaticus*		
Sarus crane	*Grus antigone*	X	X
Brolga	*Grus rubicundus*		
Buff-banded rail	*Rallus philippensis*		
Bush-hen	*Amaurornis olivaceus*		
Baillon's crake	*Porzana pusilla*		
White-browed crake	*Porzana cinerea*		
Chestnut rail	*Eulabeornis castanoventris*		
Purple swamphen	*Porphyrio porphyrio*		
Eurasian coot	*Fulica atra*		
Latham's snipe	*Gallinago hardwickii*		X
Swinhoe's snipe	*Gallinago megala*		X
Black-tailed Godwit	*Limosa limosa*	X	X
Bar-tailed Godwit	*Limosa lapponica*	X	X
Little Curlew	*Numenius minutus*	X	X
Whimbrel	*Numenius phaeopus*	X	X
Eastern Curlew	*Numenius madagascariensis*	X	X
Marsh Sandpiper	*Tringa stagnatilis*	X	X
Common Greenshank	*Tringa nebularia*	X	X
Wood Sandpiper	*Tringa glareola*	X	X
Terek Sandpiper	*Xenus cinereus*	X	X
Common Sandpiper	*Actitis hypoleucos*	X	X
Grey-tailed Tattler	*Heteroscelus brevipes*	X	X
Ruddy Turnstone	*Arenaria interpres*	X	X
Great Knot	*Calidris tenuirostris*	X	X
Red Knot	*Calidris canutus*	X	X
Sanderling	*Calidris alba*	X	X
Red-necked Stint	*Calidris ruficollis*	X	X
Pectoral sandpiper	*Calidris melanotos*		
Sharp-tailed Sandpiper	*Calidris acuminata*	X	X
Curlew Sandpiper	*Calidris ferruginea*	X	X
Broad-billed Sandpiper	*Limicola falcinellus*		X
Comb-crested Jacana	*Irediparra gallinacea*		
Bush Stone-curlew	*Burhinus grallarius*		
Beach Stone-curlew	*Esacus neglectus*		
Pied Oystercatcher	*Haematopus longirostris*		
Sooty Oystercatcher	*Haematopus fuliginosus*		
Black-winged Stilt	*Himantopus himantopus*		
Red-necked Avocet	*Recurvirostra novaehollandiae*		
Masked lapwing	*Vanellus miles*		

Common name	Scientific name	Jamba	Camba
Grey Plover	*Pluvialis squatarola*	X	X
Ringed Plover	*Charadrius hiaticula*	X	X
Little Ringed Plover	*Charadrius dubius*		X
Red-capped Plover	*Charadrius ruficapillus*		
Lesser Sand Plover	*Chardrius mongolus*	X	X
Greater Sand Plover	*Charadrius leschenaultii*	X	
Red-kneed Dotterel	*Erythrogonys cinctus*		
Oriental Plover	*Chradrius veredus*		
Black-fronted Dotterel	*Elseyornis melanops*		
Oriental Pratincole	*Glareola maldivarum*	X	X
Australian Pratincole	*Stiltia isabella*		
Silver Gull	*Larus novaehollandiae*		
Gull-billed Tern	*Sterna nilotica*		
Caspian Tern	*Sterna caspia*		X
Lesser-crested Tern	*Sterna bengalensis*		X
Crested Tern	*Sterna bergii*	X	
Roseate Tern	*Sterna dougallii*		
Black-naped Tern	*Sterna sumatrana*	X	X
Common Tern	*Sterna hirundo*	X	X
Little Tern	*Sterna albifrons*	X	X
Bridled Tern	*Sterna anaethetus*		X
Whiskered Tern	*Chlidonias hybrida*		
White-winged Black Tern	*Chlidonias leucoptera*	X	X