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# Relationships between waterbird ecology and river flows in the Murray-Darling Basin.

by
**Anthony Scott**

**Technical Report No. 5/97; June 1997**

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This report provides a detailed summary of information collected from two main sources;

- Interviews in late 1996 with two waterbird specialists, Richard Kingsford and Bill Johnson, from the NSW National Parks & Wildlife Service. Both provided a wealth of valuable information.

- Review of the published literature, in particular, articles by S Briggs, M Maher, LW Braithwaite, H Frith and R Kingsford

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*Cover Photo; Black Swan and cygnets (David Eastburn, MDBC)*

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# Summary


**a) Importance of Murray-Darling Basin wetlands**

Wetlands in the Murray-Darling Basin are very significant for waterbirds on a continental scale and 98 species were recorded in a recent Basin-wide survey. This includes waterfowl (ducks, geese, swans), grebes, pelicans, cormorants, crakes, rails, ibis, egrets, herons and migratory waders. Thirty-four waterbird species have a large component of their breeding habitat in the wetlands of the Murray-Darling Basin.

**b) Changes to the water regime**

Since European settlement the main impact on waterbirds in the Murray-Darling Basin has been the changes to the water regime of the rivers and associated wetlands. Many wetlands are receiving less water now and have decreased in area. Others are now permanently inundated and no longer have the wet and dry cycles which are essential for the wetland plants and invertebrates that many waterbirds feed on.

Changes in the flow regime of rivers and wetlands have impacted on some waterbirds more than others. Those that rely on the wetting and drying cycles of wetlands for food supply or breeding habitat, such as many of the waterfowl species, ibis, egrets and the waders, have probably suffered the most. Other species, which prefer a more permanent water supply, such as the fish-eating species, have possibly increased in abundance.

**c) Aim of this report**

If the abundance and diversity of waterbirds in the Murray-Darling Basin is to be maintained, action must be taken to reduce the impacts of river regulation and water extraction on waterbird habitat. The first step in this process is to determine the relationships between waterbird ecology and water regime. Hence, the aim of this report was to; ***review the relationships between habitat requirements of waterbirds, and flow regimes of the rivers and associated wetlands within the Murray-Darling Basin.***

**d) Ecology - Flow relationships**

Ephemeral wetlands. The Murray-Darling Basin contains a large number of ephemeral wetlands and these form a very important habitat for many species of waterbirds. When ephemeral wetlands dry up, the dead aquatic vegetation, fish and invertebrates form a rich organic substrate. In the dry period, grasses and other dryland vegetation start to grow in the basins. On reflooding, these rich organic substrates and the decaying flooded vegetation provide resources for rapidly developing populations of detritivores such as chironomids. This is quickly followed by development of a complex wetland flora and a large invertebrate population. The abundance of food provides ideal conditions for breeding of many species, including Grey Teal, Pink-eared Duck, Straw-necked Ibis and egrets. For this reason, it is vital that the wetting and drying cycles of ephemeral wetlands are maintained.

Permanent inundation of wetlands. Permanent flooding is harmful to many wetland plants since they rely on a flooding and drying cycle. Such plants need this hydrological regime for viable seed germination and root zone aeration. Permanent inundation caused by the higher water levels behind weirs has killed many River Red Gums along the Murray river. These trees are important nesting sites and many waterbird species will only nest in live red gums. Even those waterbirds that benefit in the short term from dead trees (either for nesting or roosting) will eventually lose habitat when these plants decay.

Nesting sites. To breed successfully waterbirds require suitable places in which to build their nest. Nesting sites vary from species to species, and include trees (both on branches and in hollows), Lignum, dense stands of emergent aquatic plants, and islands in the middle of lakes. It is important to manage water regimes in a way that maintains the health of vegetation used by the waterbirds for nesting. Without the necessary flooding and drying cycles the vegetation might either die or not regenerate. River Red Gums for instance benefit from periodic flooding, however they should not be continuously flooded for more than 18 months as they will decline in health and possibly die.

Stimuli for breeding. Floods induce breeding of most Australian waterbird species, and the best responses are in spring following inundation of previously dry wetlands. Breeding seasons can be extended through summer and autumn by favourable conditions. There are only a few species (such as the Musk Duck and the Blue-billed Duck) that breed entirely seasonally and are largely unaffected by water level or wetland inundation.

Lag time between flooding and breeding. If floods occur in autumn or winter, waterbird breeding will generally commence 3-6 months later in the following spring, assuming the conditions are still suitable. If floods occur in spring or early summer there is still a lag time before the birds start to breed but it will be considerably less, probably in the order of 2-3 months. During this lag time, the food supply within the wetland builds up to a level that can support a successful breeding event and also allows time for the waterbirds to increase their fat reserves before the laying of eggs. The lag time between the initial flooding and the commencement of breeding varies from species to species depending on their food requirements.

Minimum required duration of flooding. Waterbirds in the orders Pelecaniformes and Ciconiiformes take about 3.5 months to build their nests, lay and incubate their eggs, and to fledge their young (Marchant & Higgins 1990, cited by Briggs *et al.* 1994b). For a flood in spring or early summer, a 2-3 month lag time is also required and hence the minimum duration of flooding which is required for successful breeding of most waterbirds is about 5-7 months. For autumn or winter floods, a lag time of 3-6 months is needed, which results in a minimum duration of 6 - 10 months for most species.

Briggs *et al.* (1994b) reported that ducks were generally the quickest to commence breeding and require a minimum of only 3-4 months flooding of their nest sites (1-2 months of lag time plus 2 months fledging time). Studies in wetlands along the Murrumbidgee River by Briggs *et al.* (1994b) indicate that the Great Egret takes one of the longest times to breed, with a 7 month time lag followed by a 3 month period for egg laying, hatching and fledging. Hence for Great Egrets the minimum duration of flooding required is 10 months.

Desirable flood duration. Maher (1991) and Briggs *et al.* (1994b) reported that peak breeding for many waterbirds occurs approximately 3-6 months after flooding of a wetland. Assuming that some birds at the peak breeding stage are still laying (and hence need a further 3½ months), then a total of 7-10 months flooding is a desirable flood duration. Great Egrets would have one of the longest requirements with up to 9 months to peak breeding plus 3 months for laying, incubation and fledging, or a total of 12 months as a desirable duration of flooding (Briggs *et al.*1994b). The desirable duration of flooding for duck breeding is 6-7 months (4-5 months to peak number of broods plus two months fledging time) (Briggs *et al.* 1994b).

Sudden drop in water level. Colonial nesting waterbirds such as ibis and egrets will only breed successfully if water surrounds their nest sites. If the water level drops and the wetland starts to dry up before the young birds fledge, there is a great risk that the adult birds will abandon the nests. Ibis tend to be the most sensitive species to drops in water level.

Frequency of flooding. Most of the waterbirds that require flooding of wetlands for breeding are highly mobile and hence they do not need to breed on the same river system every year. Generally, somewhere in the country there is a suitable river system that has had a recent flood and this enables at least some of the individuals of the more mobile species to breed in most years. Also, it is not essential that every year waterbirds find a river system in flood, since many birds will survive for more than one breeding season.

One of the more serious problems facing waterbirds in general, is the impact that the increasing degree of river regulation is having on flood frequency. Gradually, on a nationwide basis, as the frequency of floods is reduced, the number of breeding opportunities available to these waterbirds is also slowly being reduced.

Flood volume. The large, infrequent floods are vital for the very big waterbird breeding events that have been reported in the Murray-Darling river systems. The large floods not only inundate a much larger area, and hence provide a greater abundance of food, but also provide a longer duration of inundation. This allows breeding to continue over a longer period of time.

Although the large floods provide opportunities for very large breeding events, these are not as frequent as the small to medium sized floods. It is not yet known how important the small to medium sized floods are; but they might be important for ongoing recruitment between the big breeding events. They can also have value for maintaining habitat quality which indirectly determines size and success of future breeding events.

Drought refuges. Providing dry season refuges is an important priority for waterbird conservation. The food resources of the drought refuges determine the number of birds that can exploit the next breeding opportunity. Drought refuges consist of semi-permanent and permanent inland wetlands, coastal wetlands, and wetlands permanently inundated for irrigation water storage.

**e) Other factors which impact on waterbirds.**

The regulation of flows in rivers of the Murray-Darling Basin is not the only impact on waterbird populations since European settlement. Other impacts include;

- clearing of vegetation along rivers and in wetlands
- grazing of wetlands
- introductions of exotic species
- waterfowl hunting
- changes to the water quality in rivers and wetlands (particularly increased salinity, sediments, nutrients and pesticides)
- draining of wetlands for agricultural development, construction of levees and channelling of water around wetlands
- construction of thousands of farm dams throughout the Basin

Of these other factors, the clearing and grazing of vegetation along riverbanks and in wetlands has probably had the greatest negative impact.

**f) Restoring elements of the natural flow regime.**

The best scenario for managing regulated rivers and their associated wetlands is, if possible, to reflect the natural pattern of flows, particularly in terms of critical parameters such as the season, duration and frequency of floods, and also periods of low flow. For the rivers of the Murray-Darling Basin there is considerable natural variation from year to year in both the floods and low flows, and ideally these variations should also be maintained if the species diversity of these rivers is to be maintained.

**g) Basin-wide management plan for wetlands.**

A Basin-wide approach is an essential aspect of wetland (and therefore waterbird) management. Inevitably, wetlands will be managed for a variety of purposes, and the aim should be to manage for a mosaic of wetlands with different water regimes. Some wetlands have been converted into permanent water storages, and these can provide drought refuges for some species. Other wetlands can be manipulated to retain a central area of water to partly compensate for the reduced duration of flooding which has been caused by water extraction for irrigation. And finally, many of the wetlands within the Basin should be allowed to dry out entirely between floods to reflect the natural wetting and drying cycles of these systems. A Basin-wide approach to wetland management will ensure that suitable habitat exists for the feeding and breeding requirements of all waterbird species.

**h) Saving the remaining unregulated river systems.**

In many parts of the Murray-Darling Basin, water extraction has reached a level where there is a major impact on the natural flow regime of the rivers. Although there is scope to better manage these highly regulated rivers, there is little chance of them returning to a state resembling their natural condition. There are however some rivers within the Basin, and in particular those rivers in the north-west such as the Paroo and Warrego rivers, that are relatively undeveloped and are important breeding and feeding grounds for many waterbirds. To ensure the survival of these waterbirds, it is essential that such rivers remain unregulated and free of diversions for irrigation so that they can continue to operate through the natural cycle of floods and droughts.

**i) The need for long term monitoring**.

Because we are dealing with species and ecological systems that have huge natural variability, to actually start to detect long term changes is quite difficult, and will only be noticeable over a time frame of 20-50 years. For instance on the Macquarie Marshes over a 10 year period (1983 to 1993), the number of waterbirds sighted during aerial surveys fluctuated between 2,300 and 88,600 depending on the flooding both within the Marshes and throughout eastern Australia. Therefore any attempt to monitor trends in waterbird populations needs to be undertaken over a long time period of 20-50yrs.

**j) Indicator species for monitoring programs.**

Most monitoring programmes cannot afford to monitor all waterbird species. Generally, a smaller number of key indicator species are selected. The indicator species which are selected should be sensitive to changes in the environment (such as changes to the flow regime) and should also be easy to monitor.

NSW National Parks & Wildlife Service are using the colonial breeding waterbirds as key indicator species in the Macquarie Marshes. They were selected partly because they are easier to observe (and count) than most other waterbirds, but also because they have specific breeding needs in terms of; the timing, depth and duration of flooding, and the need for specific vegetation types for nesting.

**k) Future research priorities**

Some research priorities for the conservation of waterbirds in the Murray-Darling Basin are listed below.

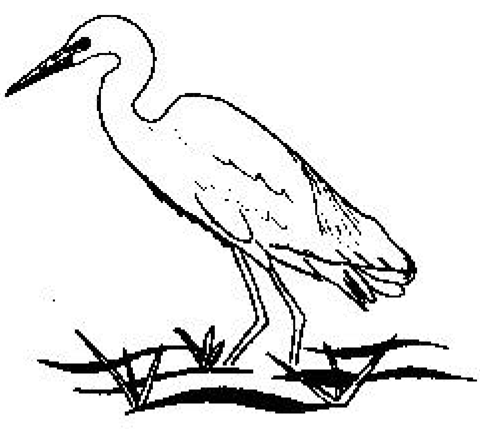
1. Further research into the relationships between the biophysical processes of wetlands and the water regime. This would include topics such as;
   - productivity, biodiversity and carbon cycles of lakes and billabongs with different flood regimes, including the effects of full drying, partial drying and permanent water
   - effects on the biophysical processes and biodiversity of rapid rises and falls of the water level

2. There is a need for studies into wetland conservation on private land, and how private landholders can be encouraged to protect wetland habitat on their properties. A significant portion of wetland habitat in the Murray-Darling Basin is on private property, and hence the preservation of this land is an important priority for waterbird survival.

3. There is a need for studies of how abundance and diversity of plants and animals can be influenced by applying different water regimes to artificially inundated wetlands (eg seasonal and steady rises and falls in water level compared with sudden rises and falls). This information would allow better management of wetlands whose primary use is for water storage, recreation etc (ie not conservation).

4. Floodplain and riparian woodlands are very important waterbird breeding habitat and a better understanding of these areas is an important research priority. Research is needed to identify how biodiversity in riparian and floodplain woodlands relates to water regimes.

5. There is increasing pressure to develop the remaining unregulated rivers within the Murray-Darling Basin, such as the Paroo and Culgoa for irrigated agriculture. There needs to be a study to determine the relative importance (on a national basis) of these rivers (and their associated wetlands) for waterbird breeding and feeding. This should be followed up by predictions of the impact on waterbirds if the development of these river systems was allowed to occur.



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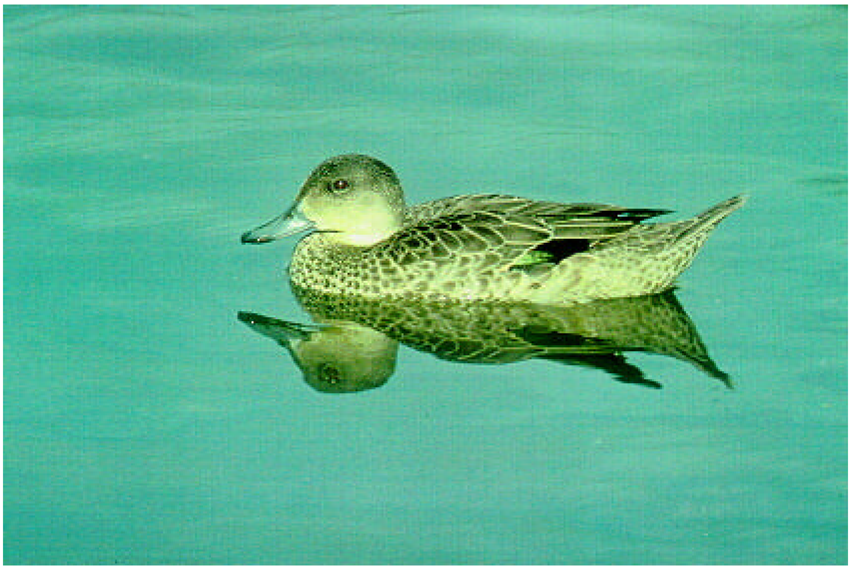


Grey Teal *(Graeme Chapman, CSIRO Division of Wildlife and Ecology)*

Great Egret *(Graeme Chapman, CSIRO Division of Wildlife and Ecology)*

# 1. Introduction

## 1.1 The importance of Murray-Darling Basin wetlands

Wetlands in the Murray-Darling Basin are very significant for waterbirds on a continental scale and 98 species have been recorded in a recent Basin-wide survey (P Straw of RAOU pers. comm.). These include waterfowl (ducks, geese, swans), grebes, pelicans, cormorants, crakes, rails, ibis, egrets, herons and migratory waders (Table 1 & Appendix 1).

**Table 1 Composition of waterbirds in the Murray-Darling Basin (*excluding rare vagrants)***
*(compiled from Williams 1983; Pizzey 1983; Slater et al. 1989, & P Straw of RAOU pers. comm. 1997;*

| Order | Family | common name | species |
|---|---|---|---|
| Podicipediformes | Podicipedidae | grebes | 3 |
| Pelicaniformes | Pelecanidae<br>Anhingidae<br>Phalacrocoracidae | pelicans<br>darters<br>cormorants | 1<br>1<br>4 |
| Ciconiiformes | Ardeidae<br>Plataleidae | herons, egrets, bitterns<br>ibis, spoonbills | 10<br>5 |
| Anseriformes | Anatidae | ducks, geese, swans | 16 |
| Gruiformes | Gruidae<br>Rallidae | cranes<br>rails, crakes, waterhens, coots | 1<br>8 |
| Charadriiformes | Charadriidae<br>Rostratulidae<br>Scolopacidae<br>Recurvirostridae<br>Laridae | plovers, dotterels<br>painted snipe<br>curlews, snipe, sandpipers, stints<br>avocets, stilts<br>gulls, terns | 6<br>1<br>approx 11<br>3<br>4 |

Kingsford *et al*. (1996) estimated that there are 18,500 wetlands in the Murray-Darling Basin and 98 of these were found (or predicted) to support 10,000 waterbirds or more. Furthermore, seven wetlands were found (or predicted) to support over 50,000 waterbirds. Only 16 wetlands in the whole of arid Australia are known to support this number of waterbirds (Kingsford *et al.*1996).

The Basin includes key waterbird breeding sites and thirty-four species have a large component of their breeding habitat in the Murray-Darling Basin (Blakers *et al.* 1984, Marchant & Higgins 1990,1993). Of these, Little Black Cormorant, Little Bittern and Glossy Ibis breed almost entirely in the Basin. The Basin also produces large numbers of Pacific Black Duck, Pink-eared Duck, Grey Teal, Hardhead, Maned Duck and Black Swan (Frith 1982), and is a stronghold for three of the less common waterfowl species, the Freckled Duck, Blue-billed Duck and Musk Duck.

After extended wet periods the Basin also provides important feeding grounds for migratory waders which travel from the northern hemisphere (Hutchison 1996).

The abundance and diversity of waterbirds in the Murray-Darling Basin are strongly dependent on the maintenance of suitable wetland habitat for both feeding and breeding. However, river regulation and water extraction have altered the flow regimes of many of these wetlands and this is having a long term impact on the waterbird population. The aim of this report is to;

- ***review the relationships between habitat requirements of waterbirds, and flow regimes of the rivers and associated wetlands within the Murray-Darling Basin.***

A better understanding of these relationships will assist with the development of water management plans for the Murray-Darling Basin. These management plans would allow for the maintenance and restoration of the critical factors of the flow regime which are required for successful waterbird breeding and survival.

## 1.2 Changes to the flow regime of rivers and wetlands

In the Murray-Darling Basin one the main impact on waterbirds since European settlement has been the changes to the flow regime of the rivers and wetlands which are essential for both waterbird breeding and survival. Most of these changes have occurred in the last 100 years and include;

a) river regulation by the construction of weirs and water storages (Pressey 1986, 1990; Briggs 1990; Thornton & Briggs 1994; Close 1990; Thomson 1994),
b) extraction of water for irrigation (MDBMC 1995, Kingsford & Thomas 1995),
c) changes in land use (Pressey & Harris 1988), and
d) impounding water in wetlands for recreation, storage of irrigation drainage water and other purposes (Thornton & Briggs 1994).

These modifications have affected the hydrology of both the rivers and the associated wetlands in four main ways (Briggs 1990, Pressey 1990, MDBMC 1995). They have;

1. reduced the average duration and extent of inundation in some wetlands,
2. reduced heights and frequencies of small to medium sized floods,
3. permanently flooded some formerly intermittently flooded wetlands,
4. altered seasonality of flooding in the middle reaches of many rivers.

In many cases these changes have been large, and overall has resulted in 87% of mean natural flows in the Murray-Darling Basin being diverted (Thomson 1994) - although some of this water returns to wetlands after being used for irrigation. Median flows at the mouth of the Murray River are now only 21% of the natural flow (MDBMC 1995).

<u>Reduced flooding of wetlands.</u> Using 50 years of flow data for the Gwydir River, NSW National Parks & Wildlife Service have done some rough calculations on the reduction in flooding in the Gwydir wetlands since flows were regulated (B Johnson pers. comm.). The type of inflow that is required for a medium sized waterbird breeding event, historically would have occurred about one in every two years. That has now decreased to about one in every ten years. The big flood events still occur but at a reduced size, and many of the smaller events have disappeared altogether (B Johnson pers. comm.). Similarly, medium sized flood events in the Barmah-Millewa forest on the Murray River have decreased in frequency from 69% of years under natural flow to only 26% of years (MDBMC 1995). Calculations by Kingsford & Thomas (1995) showed that under natural flow conditions 55% of water passing the township of Dubbo on the Macquarie River would reach the Macquarie Marshes. By 1993 this had reduced to only 21% and has caused a significant decline (40-50%) in the wetland area.

Regulation of flow and extraction of water for irrigation along the Murray river and its tributaries has not affected the large floods that occur once every ten or twenty years to the same extent as the small to medium size floods. However, if a large flood originates upstream of one of the main headwater storages, the peak flows can still be significantly reduced, especially if the storage had been at a low level prior to flooding. For example, in August 1990 the inflow to Burrendong Dam on the Macquarie River was the biggest in 105 years of record. Even though the flood mitigation zone within the storage was close to full at the commencement of the flood, it was still possible to operate the spillway gates to reduce the peak inflow of 560,000 ML/day to a peak outflow of only 165,000 ML/day (DWR 1991b). Similarly, after the extended drought of the early 1980s, Copeton Dam experienced a large flood in January 1984 which had a peak inflow of 162,000 ML/day and this was completely contained within the dam (DWR undated).

Many wetlands in the north-west of the Basin are filled by local runoff or from unregulated rivers (particularly along the Paroo River) and the flooding experienced by these wetlands has not changed greatly. Hence, the wetlands in this part of the Basin still provide excellent waterbird breeding habitat, and also good refuge habitat during dry periods (Maher 1991; R Kingsford pers. comm.). There is however continuing pressure to develop irrigated farming along these unregulated rivers (R Kingsford pers. comm.).

<u>Permanent supply of water</u>; To ensure water supply to irrigation farms and towns, the flow during dry periods has increased, and many rivers and surrounding wetlands which used to dry up periodically, now have a permanent supply of water. Also, the construction of weirs has increased the water level along large sections of river (particularly along the lower Murray) and this has resulted in the permanent inundation of billabongs and wetlands situated close to the weirs (Pressey 1986, 1990). In other parts of the Basin, wetlands have been inundated to store irrigation water (Pressey 1986, Thornton & Briggs 1994). The permanent inundation of wetlands has changed the cycling of nutrients, and this in turn has affected the food resources available to waterbirds.

<u>Changes in seasonality of flows</u>; Under the natural flow regime, rivers in the south of the Basin would generally flood in late winter and spring, inducing many waterbird species to breed and coinciding with the major breeding period (spring) in others. Many of these rivers now have their peak flows delayed until summer to provide water to irrigation areas. It is not fully understood how this change in seasonality of peak flows affects waterbird reproductive activity. The likely impacts are negative because production of many waterbird foods is stimulated by increasing warmth in spring.

The northern rivers of the Murray-Darling Basin can flood in any season although there is a higher frequency in summer. Hence any seasonal effects of river regulation on waterbird breeding are likely to be smaller than in the south.

<u>Effects on waterbirds</u>; The overall effect on waterbirds of the changes to river hydrology varies depending on the type and the extent of the changes, and also on the species of waterbird being considered. Habitat for species that use permanent water have been enhanced, while habitat for species which rely on the flooding and drying cycles of ephemeral wetlands have degraded.

<u>Other impacts</u>
Other impacts on wetlands, such as the clearing of vegetation, overgrazing and the spread of weeds also have an impact but the changes to the flow regime is the critical issue (B Johnson pers. comm.). See section 7 for further information on other impacts.

## 1.3 Changes in species diversity of waterbirds

Overall, there has probably been a slight reduction in species diversity within the Basin since European settlement (R Kingsford pers. comm.). Magpie geese, for instance, used to extend across much of the Murray-Darling Basin, but are now only occasionally seen in the northern regions (R Kingsford pers. comm.). The range of some other northern Australian species such as Black-necked Stork and Jacana also used to occur in the north of the Basin, around the Border Rivers, but their range has diminished and are now rarely seen (R

Kingsford pers. comm.). Another species that has diminished in distribution is the Brolga. In the north of Australia it is still very common but has become much less common in the south (Slater *et al.* 1989; R Kingsford pers. comm.).

## 1.4 Changes in waterbird abundance

Aerial surveys of waterbirds across eastern Australia have been undertaken since 1983 and these indicate that there might have been a decline in abundance of some species, although it is difficult to assess due to the very large fluctuations in numbers from year to year caused by long periods of flooding or drought. For instance on the Macquarie Marshes over a 10 year period (1983 to 1993), the number of waterbirds sighted during aerial surveys fluctuated between 2,300 and 88,600 due to the cycles of wet and dry periods and the associated movement of birds between catchments (Kingsford & Thomas 1995). Kingsford (pers. comm.) believes that a better indication of long term trends in waterbird numbers is the decline in wetland area that he has observed while doing the aerial surveys since 1983. He has particularly noticed changes in the Macquarie Marshes, the Gwydir wetlands, the lower Murrumbidgee and wetlands along the Border Rivers. Most of these changes are associated with the expansion of irrigated agriculture (R Kingsford pers. comm.). The steady decline in wetland area will have a long term impact on waterbird numbers.

Changes in the flow regime of rivers and wetlands have impacted on some waterbirds more than others. Those that rely on the wetting and drying cycles of wetlands for food supply or breeding habitat, such as many of the waterfowl species, ibis, egrets and the waders, have probably suffered the most. Other species, which prefer a more permanent water supply, such as the fish-eating species, have possibly increased in abundance (R Kingsford pers. comm.).

There is considerable concern about reduced breeding by egrets, especially in the Murray River wetlands (see Chesterfield *et al.* 1984, Maher 1993, Briggs *et al.* 1994b). It is likely that reduced breeding of egrets has resulted from their requirement for long floods for nesting, combined with reduced periods of wetland inundation in Murray-Darling rivers (Briggs *et al.* 1994b).

Not all agricultural developments have been adverse to waterbirds, some have been beneficial locally. There is little doubt that the introduction of improved pastures, as well as the creation of hundreds of thousands of farm dams, has favoured the Maned Duck (Frith 1982, Kingsford 1992). Also, as a result of the irrigation schemes within the Basin, several large cumbungi choked swamps of drainage water have been created and these provide good habitat for Blue-billed Duck and Musk Duck (Frith 1982).

Very little is known about impacts of European settlement and changed flow regimes on the more cryptic wetland birds such as crakes, rails and bitterns (Briggs *et al.* 1994b; R Kingsford pers. comm.).

# 2. Distribution and movements of waterbirds

## 2.1 Distribution within Australia

Frith (1982) described three fairly distinct types of distribution for waterfowl within Australia, largely determined by the climatic zones of the continent (see Table 2, Figure 1). This can equally be applied to other types of waterbird within Australia.

**Table 2 Distribution of waterfowl (ducks, geese and swan) within Australia**

| northern | southern | continental |
|---|---|---|
| Magpie Goose | Cape Barren Goose | Grey Teal |
| Plumed Whistling Duck | Black Swan | Pink-eared Duck |
| Wandering Whistling Duck | Australian Shelduck | Pacific Black Duck |
| Radjah Shelduck | Chestnut Teal | Hardhead |
| Green Pygmy Goose | Freckled Duck | Maned Duck |
| White Pygmy Goose | Australasian Shoveler | |
| | Musk Duck | |
| | Blue-billed Duck | |

- Northern species; - The typically northern species are nomadic within the tropical zone but seldom leave it. In times of drought in the tropics there may be irruptions to the south and inland but these occasions are rare. The usual range of northern species extends from King Sound in the north-west of Australia to about the Clarence River in the east (Frith 1982), and hence includes the top quarter of the Murray-Darling Basin.

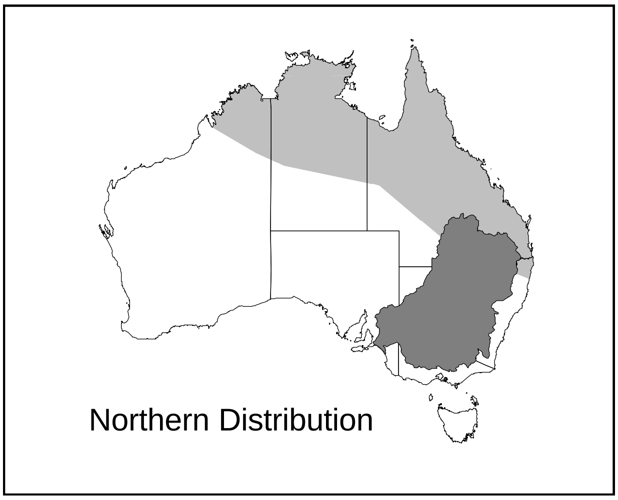
- Southern species - These species are less strongly restricted to the south than the northern ones are to the tropics. For example Black Swan, of which enormous populations exist in southern NSW, Victoria and Tasmania, has also been observed in very large numbers on Lake Wyara in south-western Queensland (Kingsford & Porter 1994). The typical range of southern species is from Geraldton in the west to Brisbane in the east, but does not extend far inland across the Great Australian Bight, avoiding the great deserts (Frith 1982). This distribution covers most of the Murray-Darling Basin.

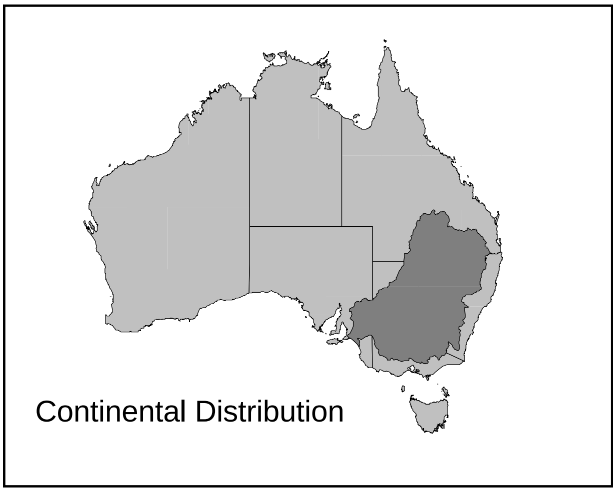
- Continental species; - These species vary greatly in the way they use the continent. For instance the Pacific Black Duck is widely distributed as a resident breeding species. Hardhead and Maned Duck are mainly southern but move throughout the continent in response to dry weather in their main habitat. Grey Teal and Pink-eared Duck are extreme nomads, moving throughout the continent in great numbers, though the greatest populations are generally in the south-east (Frith 1982).

## 2.2 Distribution within the Murray-Darling Basin.

There are five major wetland areas within the Murray-Darling Region used by waterbirds; the Murray and Riverina districts, the Macquarie-Gwydir system, the Paroo-Warrego system, the lower Darling region and the Coorong (see Figure 2).

- The **Murray and Riverina** district is located in southern NSW and northern Victoria. It includes the Murray, the lower Lachlan and the Murrumbidgee rivers. These rivers drain the region within the Murray-Darling Basin of most regular rainfall and most years they rise in level sufficiently to fill many of the lagoons, lakes and billabongs along the floodplains. This region includes the River Red Gum wetlands along the Murray River (such as Barmah-Millewa Forest and Gunbower Forest) and also along the



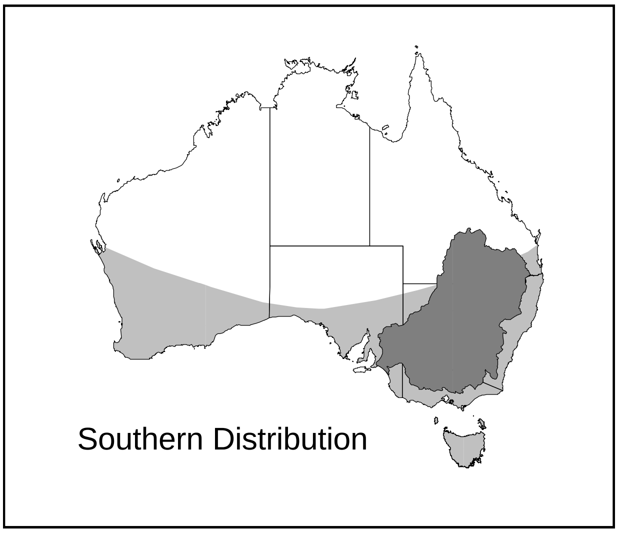




**Figure 1: Diagram showing the types of waterfowl distribution in Australia (from Frith 1982)**

Murrumbidgee River between Wagga Wagga and Hay. Other wetlands include the Great Cumbung Swamp and Lowbidgee wetlands near the Murrumbidgee-Lachlan confluence, the Booligal wetlands in the Lachlan valley, and the Hattah-Kulkyne and Kerang wetlands further down the Murray River in Victoria.

- The main tributaries of the upper Darling - in particular the **Macquarie,** and **Gwydir** rivers - are permanent streams in their upper reaches, but under natural flow conditions, did not flow far across the plains before discharging into swamps and reedbeds. In times of flood the wetland area increased and water reached the Darling. Important wetlands for waterbirds include the Macquarie Marshes, the Gwydir wetlands and the Narran Lakes.

- The **Paroo** and **Warrego** rivers rise in areas of low rainfall in southern Queensland, seldom flow and discharge into large shallow swamps, claypans and channels before reaching the Darling. Flooding, especially large scale flooding, is less frequent than in the other subregions, but when it does occur, large areas of waterbird habitat are created. Some of the lakes at the end of the Paroo, once filled, can retain water for several years and form valuable inland breeding areas, and later they provide important refuges during dry periods (Maher & Braithwaite 1992, Kingsford *et al.* 1994b). Further north in the Paroo region, Kingsford & Porter (1994) reported very high numbers of waterbirds on Lake Wyara and Lake Numalla (a total of approximately 284,000 waterbirds in March 1988) and most notably, suggested that these two lakes might be the most important dry refuge habitat on the continent for Freckled Duck. The Yantabulla Swamp which fills mainly from the Warrego river (via Cuttaburra creek), is another important wetland.

- The **lower Darling** region, which includes the Darling Anabranch and the Talyawalka Creek Lakes, contains very extensive systems of meanders, effluents, lakes and billabongs, which when flooded, create very large areas of waterfowl habitat. Kingsford *et al.* (1994a) identified Lake Menindee as one of the major wetland systems used by waterbirds in south-eastern Australia.

- **The Murray mouth and the Coorong**: As the River Murray approaches the sea in South Australia, it enters Lake Alexandrina and then divides into numerous channels which either enter the Southern Ocean or mix with waters of the Coorong, a 2-3 km wide coastal lagoon system. The Coorong is famous for its birdlife, and several hundred thousand ducks and waders may use the Coorong lagoons during summer and autumn. The most numerous species are Grey Teal, Australian Shelduck, Hoary-headed Grebe, Australian Pelican, Crested Tern, Silver Gull, Red-necked Stint, Curlew Sandpiper, Sharp-tailed Sandpiper, Red-necked Avocet and Banded Stilt (Geddes & Hall 1990). Despite the large numbers of birds, only two species breed in the Coorong in substantial numbers, the Australian Pelican and the Crested Tern (Geddes & Hall 1990).

## 2.3 Waterbird movements across Australia

Some waders which pass through the Murray-Darling Basin are migratory and follow a regular pattern of movement across Australia on the way to their breeding grounds in the northern hemisphere. The importance of inland wetlands as feeding sites for these migratory birds is not yet fully known, although on occasions very large numbers have been observed. As an example, surveys on Lake Eyre in 1990 located about 135,000 waders, including large numbers of migratory waders (Kingsford & Porter 1993). Within the Murray-Darling Basin, the RAOU Waterbird Survey has indicated that brackish wetlands in the Murrumbidgee Irrigation Area (such as Tuckerbil Swamp) and in far western NSW support the highest numbers of migratory waders (RAOU 1996; Hutchison 1996).

Many other waterbirds are nomadic and some of these species will move great distances across Australia to find suitable habitat. The development of nomadism among many of the Australian waterbirds is an adaptation to the erratic climate that prevails over the continent (Braithwaite 1975; R Kingsford pers. comm.). Generally, somewhere in the country there is a river system that has had a recent flood and this enables the more mobile species to feed and breed. One of the more serious problems in terms of river regulation is that, gradually, on a nationwide basis, the degrees of freedom available to these waterbirds are slowly being reduced (Kingsford 1996).

The results of ecological studies suggest that food, ultimately determined by rainfall, is the major factor that controls the movements of the nomadic species of waterbirds (Braithwaite 1975; Briggs 1992; Lawler *et al.* 1993; Kingsford 1996). In most cases the food supply is directly geared to rainfall (either locally or in the upper catchment) which replenishes the floodplain wetlands, and leads to the appearance of aquatic plants, macroinvertebrates, and vertebrate species such as frogs and fish (Briggs & Maher 1985; Maher & Carpenter 1984; Crome 1986).

There are substantial species differences in the degree of mobility of waterbirds, and this is well demonstrated by the different waterfowl species. The Grey Teal and Pink-eared Duck are noted for their rapid long ranging movements (Frith 1982, Lawler *et al.* 1993 ). These species have the potential to gain the most (in terms of food from recently flooded areas) from their powers of movement. In others, such as the Pacific Black Duck, Black Swan, Hardhead and Australian Shelduck, movements are more limited which is in accordance with their requirement of more permanent habitats (Braithwaite 1975).

There is however a bias in the nomadic movements towards the coast, particularly in the south-east of the continent, during extended dry periods. These areas are more regularly watered than elsewhere and therefore are more reliable habitats (Frith 1962; Gosper *et al.* 1983; Braithwaite 1975; B Johnson pers. comm.; R Kingsford pers. comm.). When floods arrive, they will disperse inland again.

# Wetlands of the Murray-Darling Basin

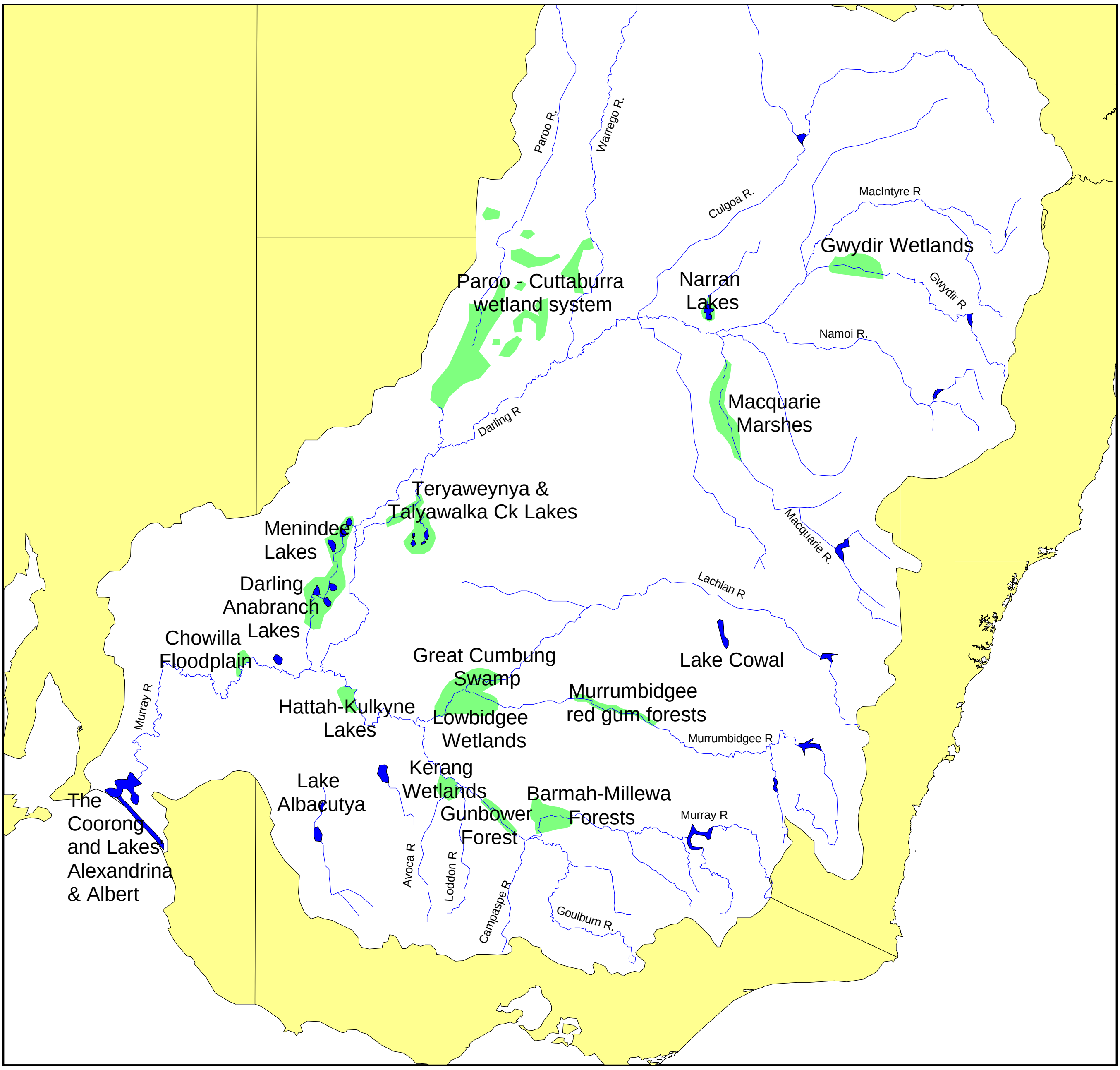



Figure 2

# 3. Waterbird habitat

Waterbird species depend on wetlands for feeding and breeding. There is a large range of wetland habitats within the Murray-Darling Basin that are used by waterbirds and the importance of each type of habitat appears to lie in their provision of abundant food resources. Different habitats provide different foods, and as each waterbird species tends to specialise in a range of food types, species utilisation of habitat also varies (see for example, Frith 1982, Briggs 1979,1982) Many types of wetland habitat are dynamic systems with specific and usually temporary qualities, and successional change within these wetlands is the basis of good habitat. Habitat is not provided by just "any area of water" (Braithwaite 1975). The diversity of waterbird species in any region depends on the variety of wetland habitats available.

## 3.1 Habitat availability within the Basin

The frequency of flooding is highly variable between inland catchments. Both floods and droughts tend to be a regional phenomenon. At the local scale (wetland) the probability of water being present is low; at the regional scale (catchment) it is higher; and at the continental scale is highest. Only during exceptional events is water not present in at least some wetlands of the inland region (Maher 1991). An analysis by Braithwaite (1975) of the flood patterns of six rivers in the Murray-Darling Basin, indicated that in most years floods occur on one or more rivers. In less than 10% of the time there was no flooding. This suggests that habitat is nearly always available somewhere within the Basin, either in the form of floodwater or in the form of semi-permanent or permanent habitats, replenished with water in the recent past.

During extended droughts, waterbirds will be forced to move to the more permanent waterbodies. Important drought refuges include; permanent artificial wetlands with shallow backwaters, large permanent or semi-permanent natural lakes with shallow edges, and saline groundwater disposal sites (Hutchison 1996). In times of drought many waterbirds will also move to wetlands along the east coast of the continent.

## 3.2 Importance of ephemeral wetlands

Recently flooded ephemeral wetlands provide an abundance of food for many species of waterbirds. When ephemeral wetlands dry up, the dead aquatic plants, fish and invertebrates form a rich organic substrate. In the dry period, grasses and other dryland vegetation start to grow in the basins. On re-flooding, these rich organic substrates and the decaying flooded vegetation provide resources for rapidly developing populations of detritivores such as chironomids (Maher & Carpenter 1984). This is quickly followed by development of a complex wetland flora and large invertebrate population (Crome 1988). The abundance of food provides ideal conditions for breeding of many species, including Grey Teal, Pink-eared Duck, Straw-necked Ibis and egrets.

The successional changes that occur in wetlands as they fill up and then dry out have a strong influence on what waterbird species will be present at any one time. As the wetland fills up there will be a large number of species that can feed on benthic invertebrates. If the water remains for a couple of years or more, the fish population slowly builds up in numbers and fish eating waterbirds such as cormorants and pelicans arrive. As the wetland starts to dry out, the salinity rises and the water clarity increases. The fish are eventually knocked out by the high salinity and salt tolerant aquatic macrophytes grow in the shallow clear water. This attracts the herbivorous species such as Black Swans. Finally, as the wetland dries up completely, resident and migratory wading species feed in the mud flats. So there are very complex population dynamics and life cycles associated with the wetting and drying phases of ephemeral wetlands.

An example of the successional change that occurs when waterbodies dry up was observed a couple of years ago at Menindee Lake, a semi-permanent regulated waterbody along the lower Darling river (R Kingsford pers. comm.; GEO 1996). It started to dry up and as the water level dropped it was operating more like a natural wetland with a wetting and drying cycle. A huge abundance and diversity of waterbirds started to feed in the shallow water. Normally Lake Menindee would have up to 10,000 waterbirds, most of which would be pelicans and cormorants, but as it dried up there were 80,000 birds present (R Kingsford pers. comm.). Lake Menindee is usually deep and turbid with only a small margin around the edges that is suitable for waders, but when it started to dry up the area suitable for waders became extensive. The successional changes of ephemeral wetlands are also being studied by Kingsford (pers. comm.) at Salisbury Lake near White Cliffs. This is a natural wetland which might contain water for up to three years and then completely dry out. descriptions of the successional changes have also been provided for a wetland near Booligal (Maher 1984; Maher & Carpenter 1984; Briggs & Maher 1985; Crome 1988) and for wetlands along the Paroo River in north-western NSW (Maher 1991).

## 3.3 Permanent inundation of wetlands

Permanent flooding is harmful to many wetland plants since they rely on a flooding and drying cycle. Such plants need this hydrological regime for viable seed germination and root zone aeration. Permanent inundation caused by the higher water levels behind weirs has killed many River Red Gums along the Murray river. These trees are important nesting sites and many waterbird species will only nest in live red gums. Even those waterbirds that benefit in the short term from dead trees (either for nesting or roosting) will eventually lose habitat when these plants decay (Kingsford 1995, Briggs *et al.* 1997).

Initially the permanent inundation of natural wetlands provides good habitat for fish and waterbirds as organic matter and nutrients are released and invertebrate populations build up after flooding. With extended inundation (>2 yrs), biodiversity decreases (Cadwallader 1978; Maher 1990). Permanently flooded wetlands along the Murrumbidgee River and the Darling River support waterbird communities dominated by fish eating waterbirds. These have replaced duck and wading bird communities (Kingsford 1995).

Briggs *et al.* (1994a) studied the changes in abundance and diversity of waterbirds at Tombullen wetland near the Murrumbidgee River over a 10 year period after it was converted to a permanent water storage in 1980. Abundance of waterbirds, the number of species present and the number of breeding species all diminished. An analysis of data for each species indicated that 14 species were disadvantaged, six were not obviously affected and only two species appeared to have benefited. Many of these highly controlled systems experience large and rapid fluctuations in water level and tend to have low numbers of aquatic plants and invertebrates (Broome & Jarman 1983). Hence, they are generally unattractive to waterbirds, compared with more natural wetlands where water levels rise and fall more slowly and evenly (Briggs *et al.* 1994b).

Semi-permanent or permanent waterbodies are generally more favoured by the fish-eating waterbird species such as cormorants, Darter and Australian Pelican. The stiff-tailed diving ducks (Blue-billed Duck and Musk Duck) also tend to favour more permanent waterbodies and so do crakes and rails which inhabit emergent aquatic vegetation along the shallow edges of lakes, rivers and wetlands.

## 3.4 Saline and freshwater wetlands

Both saline and freshwater wetlands occur naturally in the Murray-Darling Basin. In some parts of the Basin the number of saline wetlands has probably increased in the last few decades due to agricultural practices such as land-clearing and irrigation which have caused groundwater tables to rise and brought salts to the surface.

Kingsford & Porter (1994) studied waterbirds on an adjacent freshwater wetland (Lake Numalla) and saline wetland (Lake Wyara) in south-western Queensland. They found that the saline wetland had about ten times more waterbirds (mainly ducks, herbivores and small wading birds) than the freshwater wetland (mainly piscivores and large wading birds).

On the saline wetland there was a higher number of waterbirds that feed on invertebrates, and this could be explained by the much greater abundance of food. The saline water causes clay particles to flocculate and settle out of the water column, allowing light to penetrate and submerged macrophytes to establish. These aquatic macrophytes not only provides food for herbivorous waterbirds but also supports a great abundance of zooplankton which in turn provide food for other species of waterbird .

The high turbidity of the freshwater lake resulted in less primary productivity and hence less submerged macrophytes and zooplankton. The high number of fish-eating birds and large wading waterbirds on the freshwater wetland was attributed to the occurrence of prey such as fish, shrimps and frogs which cannot tolerate the very high salinities in Lake Wyara, particularly when it start to dry out.

Although saline wetlands might have a greater abundance of waterbirds than freshwater ones, many species depend on freshwater wetlands for breeding. Favoured nesting sites for birds like herons, egrets, ibis, spoonbills, darters and cormorants are in living trees and Lignum bushes (*Muehlenbeckia florulenta)* and this vegetation cannot tolerate high salinity.

When wetlands start to dry up, the salinity tends to increase, and this leads to a successional change of food resources which in turn leads to a change in the waterbird species that are present.

# 4. Waterbird food

Reproductive success for waterbirds depends on three main factors;

- food availability for adult birds to gain breeding condition for egg formation,
- provision of secure nesting sites, and
- food availability for the young birds.

Therefore a reliable supply of food is essential for successful breeding. Most Australian waterbirds obtain this food in, or on the edges of water, and only a few (such as the Maned Duck and Straw-necked Ibis) consistently collect large quantities of food on dry land.

## 4.1 Types of food eaten

The location within a wetland where a certain species will feed varies, as does the food eaten. There are three main types of food eaten, although many species will on occasions eat a whole range of different food items;

a) Fish; - fish-eating birds include;

- Australian Pelican,
- cormorants,
- Darter and
- terns.

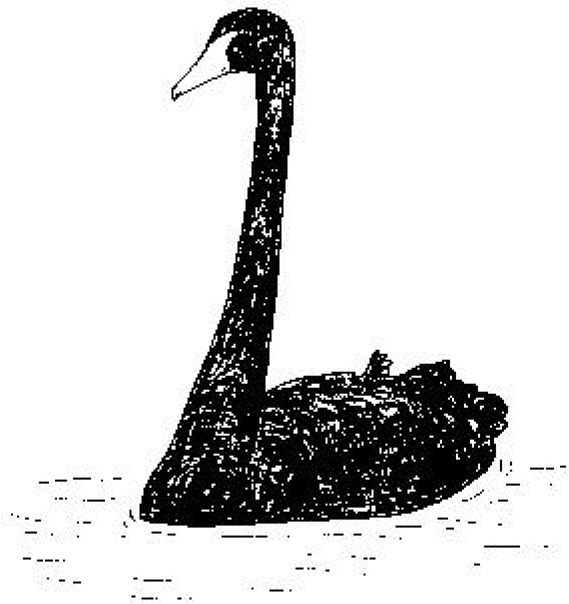
b) Plant material; - examples of herbivorous species are;

- Black Swans and coots which feed mainly on aquatic macrophytes,
- Magpie Geese, Plumed Whistling Ducks and Maned Ducks which feed almost entirely by grazing seedheads, buds, leaves and other plant parts of both wetland and dry land vegetation,

c) Invertebrates and other small animals; - studies by Paterson & Walker (1974), Maher (1984), Maher & Carpenter (1984), and Crome (1986) indicated a very high level of production of invertebrates (and also small vertebrates such as frogs) in shallow, ephemeral wetlands, and this provides an excellent food source for many species of waterbirds. Examples are;

- Pacific Black Duck, Grey Teal, and Chestnut Teal which dabble in shallow water and mud for invertebrates and seeds;
- Pink-eared Duck and Australasian Shoveler which collect invertebrates in shallow water by filtering water and mud through the bill;
- wading birds which eat crustaceans, worms and other invertebrates in mud flats;
- egrets which hunt in shallow water both for invertebrate species (such as crustaceans), and vertebrate species (such as frogs, tadpoles and small fish);
- Glossy Ibis, Straw-necked Ibis and Australian White Ibis which capture beetles, grubs, and insects, by probing along the water's edge or in damp ground. Straw-necked Ibis also forage in damp ground away from waterbodies;
- spoonbills which capture aquatic invertebrates by walking through shallow water and using their flat bill to sieve the water and wet mud;
- Rufous Night Heron which has similar requirements to egrets, they hunt for fish, crustaceans, frogs and tadpoles. It is also thought that they might prey on abandoned fledglings of other waterbirds; they tend to hang around egret colonies even if they are not themselves breeding (B Johnson pers. comm.);
- Blue-billed Duck which feeds mainly on benthic invertebrates by diving underwater and Musk Duck which feeds entirely by diving.

Many waterbirds have similar food habits, at least superficially, and when large mixed flocks occur on the same wetland it might seem that they are competing for the same food, but this is not necessarily so.  Each species tends to collect different food items, or the same items from quite different parts of the wetland.



# 5. Waterbird ecology; breeding

## 5.1 Stimuli for breeding

The stimulus for breeding by Australian waterbirds has received considerable attention. Extreme positions are on the one hand that flooding and/or rainfall are the primary stimulants, on the other that breeding is controlled by photoperiod. After reviewing the literature, particularly the work of Fullagar *et al.* (1986) and Schodde (1982), and observing the responses of waterbirds to flooding on the Paroo River, Maher (1991) concluded that floods induce breeding of most waterbird species, and the best responses are in spring following inundation of previously dry wetlands. Breeding seasons can be extended through summer and autumn by favourable conditions. Kingsford (pers. comm.), Johnson (pers. comm.) and Briggs (1990) have all reached similar conclusions. Only two species, the Musk Duck and the Blue-billed Duck, breed entirely seasonally and are largely unaffected by water level or wetland inundation (Briggs 1990). Briggs (1990) has compiled a summary (Table 3) of the main breeding stimuli for many of the waterbirds in the Murray-Darling Basin.

**Table 3 Main breeding stimuli for Murray-Darling Waterbirds (from Briggs 1990)**

| common name | breeding stimulus |
|---|---|
| Great Crested Grebe | flooding |
| Hoary-headed Grebe | flooding |
| Australasian Grebe | flooding; seasonal |
| Australian Pelican | flooding |
| Darter | flooding |
| Great Cormorant | seasonal; flooding |
| Pied Cormorant | seasonal; flooding |
| Little Black Cormorant | seasonal; flooding |
| Little Pied Cormorant | flooding; seasonal |
| Pacific Heron | flooding; seasonal |
| White-faced Heron | flooding; seasonal |
| Great Egret | flooding; seasonal |
| Little Egret | flooding |
| Intermediate Egret | flooding; seasonal |
| Rufous Night Heron | flooding |
| Glossy Ibis | flooding |
| Australian White Ibis | flooding; seasonal |
| Straw-necked Ibis | flooding |
| Royal Spoonbill | seasonal; flooding |
| Yellow-billed Spoonbill | seasonal; flooding |
| Black Swan | flooding |
| Freckled Duck | flooding |
| Australian Shelduck (Mountain Duck) | flooding; seasonal |
| Pacific Black Duck | flooding; seasonal |
| Grey Teal | flooding |
| Chestnut Teal | flooding; seasonal |
| Australasian Shoveler | flooding |
| Pink-eared Duck | flooding |
| Hardhead | flooding; seasonal |
| Maned Duck (Wood Duck) | rainfall; seasonal |
| Blue-billed Duck | seasonal |
| Musk Duck | seasonal |
| Black-tailed Native Hen | flooding |
| Dusky Moorhen | flooding; seasonal |
| Purple Swamphen | seasonal; flooding |
| Eurasian Coot | flooding |
| Brolga | flooding |

## 5.2 Breeding season and lag times

Observations both in the north and the south of the Murray-Darling Basin indicate that the most successful waterbird breeding occurs following a flood in late winter, spring or early summer. (Briggs 1990, 1994; R Kingsford pers. comm.; Maher 1991; B Johnson pers. comm). Before waterbirds can breed successfully they need to build up their fat reserves and this can only be achieved if there is a plentiful supply of food available. The increasing temperature during spring and early summer tends to favour the production of wetland biota such as invertebrates and aquatic plants and these provide the food resources for the waterbirds. During winter there is less food available and the chances of a successful breeding event are considerably less. Johnson (pers. comm.) reported that in the Narran Lakes a breeding event was abandoned in very cold weather in early June, (even though no drop in water level had occurred). The breeding had started late in summer and there was considerable success early on but towards the end about 5,000-10,000 young birds were abandoned.

A typical example of breeding season is provided by the Intermediate Egret. It has been recorded in the Macquarie Marshes to commence a successful breeding event as early as September and as late as January (B Johnson pers. comm.). The January event finished in May, so this indicates that breeding can commence as early as September and finish as late as May.

If floods occur in autumn or winter, waterbird breeding will generally commence 3-6 months later in the following spring, assuming the conditions are still suitable. If floods occur in spring or early summer there is still a lag time before the birds start to breed but it will be considerably less, probably in the order of 2-3 months (Johnson pers. comm. 1996, Briggs *et al.* 1994b, Maher 1991). During this lag time, the food supply within the wetland builds up to a level that can support a successful breeding event and also allows time for the waterbirds to increase their fat reserves before the laying of eggs.

The lag time between the initial flooding and the commencement of breeding varies from species to species depending on their food requirements. For waterbirds such as the Straw-necked Ibis that feed on invertebrates, their lag time will be shorter than that for the fish-eating waterbirds. This simply reflects the amount of time it takes for different food resources to increase in abundance (B Johnson pers. comm., R Kingsford pers. comm.).

## 5.3 Duration of breeding

**a) Minimum required duration of flooding.** Waterbirds in the orders Pelecaniformes and Ciconiiformes take about 3.5 months to build their nests, lay and incubate their eggs, and to fledge their young (Marchant & Higgins 1990, cited by Briggs *et al.* 1994b). For a flood in spring or early summer, a 2-3 month lag time is also required and hence the minimum duration of flooding which is required for successful breeding of most waterbirds is about 5-7 months. For autumn or winter floods, a lag time of 3-6 months is needed, which results in a minimum duration of 6 - 10 months for most species.

Briggs *et al.* (1994b) reported that ducks were generally the quickest to commence breeding and require a minimum of only 3-4 months flooding of their nest sites (1-2 months of lag time plus 2 months fledging time). Studies in wetlands along the Murrumbidgee River by Briggs *et al.* (1994b) indicate that the Great Egret takes one of the longest times to breed, with a 7 month time lag followed by a 3 month period for egg laying, hatching and fledging. Hence for Great Egrets the minimum duration of flooding required is 10 months.

**b) Desirable flood duration.** Maher (1991) and Briggs *et al.* (1994b) reported that peak breeding for many waterbirds occurs approximately 3-6 months after flooding of a wetland. Assuming that some birds at the peak breeding stage are still laying (and hence need a further 3½ months), then a total of 7-10 months flooding is a desirable flood duration. Great Egrets would have one of the longest requirements with up to 9 months to peak breeding plus 3 months for laying, incubation and fledging, or a total of 12 months as a desirable duration of flooding (Briggs *et al.*1994b). The desirable duration of flooding for duck breeding is 6-7 months (4-5 months to peak number of broods plus two months fledging time) (Briggs *et al.* 1994b).

## 5.4 Rise and fall of water level

Colonial nesting waterbirds such as ibis and egrets will only breed successfully if water surrounds their nest sites. If the water level drops and the wetland starts to dry up before the young birds fledge, there is a great risk that the adult birds will abandon the nests (Briggs 1990; B Johnson pers. comm.; R Kingsford pers. comm.). Ibis tend to be the most sensitive species to drops in water level (B Johnson pers. comm.; R Kingsford pers. comm.).

The importance of avoiding sudden drops in water level was demonstrated recently (November 1996) in the Macquarie Marshes, where a colony of ibis (approx 400 nests and 1000 chicks) abandoned their nests when water receded from the site after the flow in the river was reduced from over 1500 ML/day to 400-500 ML/day (DLWC 1997, B Johnson pers. comm.). Similar incidents in other wetlands have also been reported.

A drop in water level is probably an indicator to the birds that food resources might decline and not be sufficient to complete the breeding event. The waterbirds are more sensitive to drops in water level early in the breeding event. This is probably a survival adaptation whereby the birds do not put lots of energy into breeding if the water level starts dropping early on, but if it starts dropping later on in the breeding cycle it is more likely to be worth their while persisting (R Kingsford pers. comm.; B Johnson pers. comm.).

Rapid rises in water level are not so critical, and in many floodplain and terminal wetlands, such as the Macquarie Marshes, this does not often occur as additional water tends to spread out over the surrounding land rather than cause a rapid rise in water level (B Johnson pers. comm.).

## 5.5 Depth of flooding

Except for the fish-eating waterbirds, the depth of flooding is not directly an important variable. It is however an indicator of the extent of flooding and the length of time that the floodwaters will remain (R Kingsford pers. comm.). The deeper the water the more insurance there is against dropping water levels, and hence the greater chance of breeding success. Johnson (pers. comm.) observed at a recent flood in the Gwydir river that there was a drop in the water level and this caused the water around the breeding colony to recede. Birds on the fringe of the breeding colony abandoned their nests but birds breeding in Lignum bushes only 20m away still had water under them and they did not abandon their nests. So the deeper the water the longer the period that suitable conditions are likely to exist.

## 5.6 Frequency of flooding

Most of the waterbirds that require flooding of wetlands for breeding are highly mobile and hence they do not need to breed on the same river system every year. Under natural flow conditions, generally somewhere in the country there was a suitable river system that had recently flooded and would enable at least some of the individuals of the more mobile species to breed in most years.

Also, it is not essential that every year waterbirds find a river system in flood, since many birds will survive for more than one breeding season. Waterbirds become sexually mature at the age of one or two years and have a life expectancy ranging from 3-4 years for ducks, and up to 8 years for larger birds such as ibis (B Johnson pers. comm., R Kingsford pers. comm.). Bird banding studies have reported some waterbirds to live up to 20 years (B Johnson pers. comm.; R Kingsford pers. comm.).

However, one of the more serious problems facing waterbirds in general, is the impact that the increasing degree of river regulation is having on flood frequency. Gradually, on a nationwide basis, as the frequency of floods is reduced, the number of breeding opportunities available to these waterbirds is also slowly being reduced (R Kingsford pers. comm.).

## 5.7 Large floods versus small floods

Waterbird breeding in the Macquarie Marshes is a good example of how the size of flood affects the size of the breeding event for waterbirds. Studies have indicated that a minimum volume of 250,000 ML over a 7 month period (measured just upstream of the Marshes) is required to ensure the success of colonial breeding waterbirds such as Straw-necked Ibis and Intermediate Egrets (NPWS/DLWC 1996). At flows below this threshold, the area and duration of inundation might not be sufficient to support a successful breeding event. As the volume of water increases above this threshold, there is a sharp increase in the number of birds breeding. For instance in 1990 when the water volume over the 7 month period was 485,000 ML, there were 17,200 pairs of Intermediate Egrets and 65,000 pairs of ibis breeding in the Marshes (DLWC/NPWS 1996; B Johnson pers. comm.).

The large, infrequent floods are vital for the very big waterbird breeding events that have been reported both in the Murray-Darling river systems and in the Lake Eyre Basin (R Kingsford pers. comm.; B Johnson pers. comm.). The large floods not only inundate a much larger area, and hence provide a greater abundance of food, but also provide a longer duration of inundation. This allows breeding to continue over a longer period of time.

Although the large floods provide opportunities for very large breeding events, these are not as frequent as the small to medium sized floods. It is not yet known how important the small to medium sized floods are; but they might be important for ongoing recruitment between the big breeding events (B Johnson pers. comm.). They can also have value for maintaining habitat quality which indirectly determines size and success of future breeding events.

## 5.8 Nesting sites

To breed successfully waterbirds require suitable places in which to build their nest. Nesting sites vary from species to species, and include trees (both on branches and in hollows), Lignum, reeds and rushes, and islands in the middle of lakes.

Some waterbirds nest singly where ever suitable conditions exist (such as Australasian Grebe and Musk Duck) while others breed in colonies at very specific locations in the larger wetlands of the Murray-Darling Basin (such as ibis and egret colonies in the Macquarie Marshes).

A summary of the most important sites used for nesting in the Murray-Darling Basin are discussed below. Further details for each species can be obtained from Marchant & Higgins (1990, 1993) and Pizzey (1983)

- **Trees - stick nests in branches;** Many species of waterbirds, such as cormorants, herons, and egrets, build stick nests in trees next to lakes or wetlands. Often these nests are built in branches that overhang open water. The most common species of tree used is the River Red Gum. Many of these birds will only nest in live River Red Gums although a few, such as Darter, Great Cormorant and Pacific Heron also use dead trees (Briggs *et al.*1994b). The floodplain forests along the Murray and Murrumbidgee rivers provide extensive and valuable nesting sites in River Red Gums. Further information on the nesting of waterbirds in River Red Gums can be obtained from Briggs *et al.*(1994b).

- **Trees - hollows;** Many ducks (but not all) nest in hollows of trees near water. The more common tree species include Coolibah (*Eucalyptus coolabah*), Black Box (*E. largiflorens*) and River Red Gum, although River Red Gums generally provide the best hollows. Following flood producing rains on the Paroo River in January 1984, Maher (1991) reported that every accessible River Red Gum hole had either Grey Teal, Pacific Black Duck or Maned Duck laying or incubating within it. Although many species of waterfowl use hollows, only the Maned Duck is confined to hollows for nesting.

- **Lignum;** Many species of waterbird including colonial breeders such as Straw-necked Ibis and Glossy Ibis, build their nests in bushes of Lignum. Maher (1991) observed during flooding along the Paroo River that 11 species built nests only in Lignum and a further two species preferred it to other sites. The protection of Lignum, therefore, is a particularly important issue in waterbird and wetland conservation.

- **Waterplants;** Some species, such as the ibises, spoonbills and Australian Bittern will, on occasions, create a platform nest by trampling down rushes, reeds or Cumbungi. Others, such as the grebes, form a nest at water level in dense stands of reeds and rushes by collecting together a mass of submerged and floating waterplants. The waterhens, crakes and rails also build their nests under the cover of dense emergent waterplants.

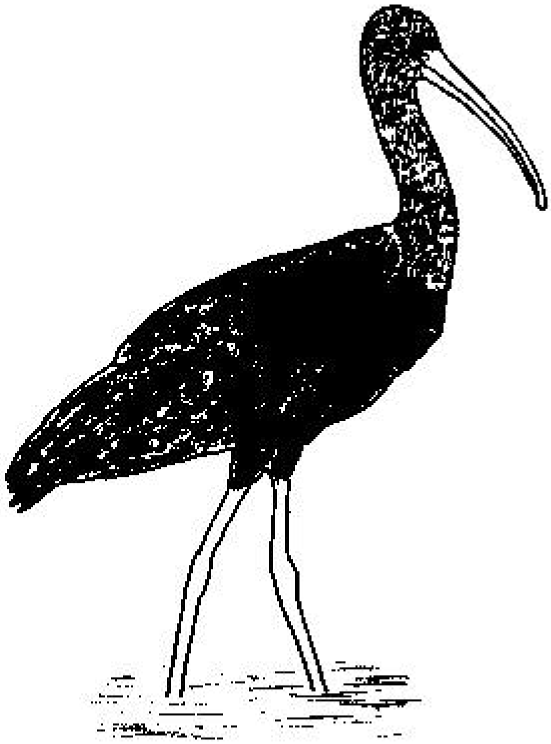
- **Islands in salt lakes;** Swans and pelicans build nests on the ground, generally on islands surrounded by water deep enough to deter predators (Maher 1991). The most common type of waterbody in inland Australia that has suitable islands are the salt lakes. Pelicans also breed at suitable sites along the coast.

It is important to manage water regimes in a way that maintains the health of vegetation used by the waterbirds for nesting. Without the necessary flooding and drying cycles the vegetation might either die or not regenerate. River Red Gums for instance benefit from periodic flooding (Bren 1987, 1988, 1990), however they should not be continuously flooded for more than 18 months as they will decline in health and possibly die (Leitch 1989, Briggs 1994a,b). Other wetland vegetation, such as Black Box (Jolly & Walker 1996) and Lignum (Craig *et al.* 1991) need floods to stimulate regeneration, and hence if these floods do not occur these species will gradually decline in abundance.

## 5.9 Applying breeding data to other parts of Basin

Most of the relationships between waterbird breeding and flooding of wetlands appears to apply across the Murray-Darling Basin and not be site specific. The one exception to this might be the season of breeding. In the south of the Basin, the best time for breeding appears to be spring and early summer, however in the north of the Basin breeding might extend into late summer if sufficient rainfall occurs.

Johnson (pers. comm.) reported an example of applying information learnt from waterbird breeding in one wetland to that in another wetland. NSW National Parks & Wildlife Service gathered information on the breeding requirements of colonial breeding birds in the Macquarie Marshes and used it successfully in 1996 to recommend water requirements for birds breeding in the Gwydir wetlands. The breeding requirements of birds in the Gwydir wetlands were similar to those in the Macquarie Marshes.



# 6. Waterbird ecology; survival

Drought has a big impact on waterbirds, with two main effects. There is an impact on adult survival which is due to drying up of wetlands and therefore loss of food resources, and the second effect is the lack of stimulus to breed, which in turn is related to the lack of food (R Kingsford pers. comm.).

Localised droughts have less impact than Australia-wide droughts caused by El Nino effects. When extended droughts occur across most of Australia, waterbirds will be forced to move great distances across the continent in search of habitat.

The aerial surveys of eastern Australia provide an indication of the impact that extended droughts can have on both the distribution of waterbirds and on overall abundance. Numbers surveyed each year can fluctuate by an order of magnitude (Kingsford *et al.* 1994, 1993, 1992, 1991, 1990, 1989, 1988, Braithwaite *et al.* 1987, 1986a, 1986b, 1986c, 1985).

An example of the large fluctuations that can occur has been observed for the Australian Pelican. During extended wet periods in the early 1970s they moved inland to breed and there was a very large increase in numbers. As conditions became drier during the late 1970s and early 1980s they moved away from their breeding grounds and became more common on estuarine and other permanent wetlands in search of food (R Kingsford pers. comm.; Briggs 1990, Van Tets 1983). Most of the pelicans on these wetlands appeared debilitated and many died from unknown causes, probably starvation and disease (Briggs 1990). Pelicans are large birds and easily seen, dead or alive. Many other, less easily observed waterbirds presumably went through similar population fluctuations during this period (Briggs 1990).

Braithwaite (1975) postulated that waterbird populations were controlled in the long term by the availability of wetlands during these widespread dry periods. The food resources of the drought refuges determine the number of birds that can exploit the next breeding opportunity (Maher 1991).

Providing dry season refuges is an important priority for waterbird conservation. Residual populations should be supported during drought , to later recolonise breeding habitats in temporary wetlands (Briggs 1990).

## 6.1 Drought refuges - inland wetlands

Except in severe droughts, surface water is present in one or more catchments of the arid/semi arid zones of Australia, enabling waterbird populations to survive between flood events (Braithwaite *et al.* 1986b; R Kingsford pers. comm.). Examples of wetlands within the Murray-Darling Basin that retain water for long periods of time and can provide drought refuges, include Narran Lake, wetlands along the Paroo River (Maher 1991), and parts of the Macquarie Marshes (R Kingsford pers. comm.).

## 6.2 Drought refuges - coastal wetlands

Coastal wetlands provide drought refuges for many waterbird species that inhabit the Murray-Darling Basin, especially during extended droughts when many of the semi-permanent inland wetlands dry up (see for example Frith 1962, Carrick 1962, Gosper *et al.* 1983).

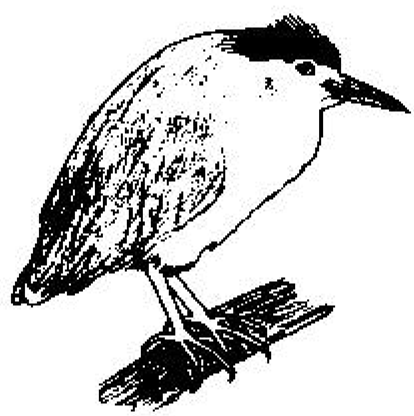
Many coastal wetlands have been drained for agricultural or urban development, and this reduces the availability of drought refuges for waterbirds during extended dry periods.

## 6.3 Drought refuges - permanent water storages

Some ephemeral wetlands in the Murray-Darling Basin are now permanently inundated for irrigation water storage, and these can serve as drought refuges for waterbirds. Briggs (1990) reported that numbers of ducks in Barren Box Swamp, a now permanently flooded but formerly ephemeral Black Box depression, tend to be high when local rainfall is low and vice versa. However, Briggs (1990) questioned how well waterfowl survive on such wetlands during dry periods. Food may be difficult to find, body reserves may drop and starvation, disease and predation may be high.

Kingsford (pers. comm.) also believed that permanent water storages act as drought refuges for some waterbirds, but was not convinced that they have the diversity of food resources in them to act as drought refuges for all species. They might provide good habitat for fish eating species and also some species of duck, but often will not be suitable for the wading species, because many of the storages are deep sided and experience very large fluctuations in water level which prevents the establishment of a diverse aquatic community (Braithwaite 1975, Broome & Jarman 1983) This is particularly so for the water storages in the upper reaches of the Basin such as Burrinjuck, Blowering and Wyangala.

There are some storages however, where many of species of waterbirds occur, including some waders. Lake Brewster on the lower reaches of the Lachlan River is a good example. Under natural conditions it was a shallow ephemeral lake, and although the water level is now kept artificially high, it is still suited to a variety of wading species because of its shallow edges (R Kingsford pers. comm.).



# 7. Other factors which impact on waterbirds

The regulation of flows in rivers of the Murray-Darling Basin is not the only impact on waterbird populations since European settlement. Other impacts include;

- clearing of vegetation along rivers and in wetlands
- grazing of wetlands
- introductions of exotic species
- waterfowl hunting
- changes to the water quality in rivers and wetlands (particularly increased salinity, sediments, nutrients and pesticides)
- draining of wetlands for agricultural development, construction of levees and channelling of water around wetlands
- construction of thousands of farm dams throughout the Basin

Of these other factors, the clearing and grazing of vegetation along rivers and in wetlands has probably had the greatest negative impact. Brief details of each factor are provided below.

## 7.1 Clearing of vegetation in wetlands and along rivers

Loss of floodplain habitat due to land clearing results in loss of both feeding and breeding areas for waterbirds. This has been a problem in many parts of the Murray-Darling Basin. Examples include the Murray River floodplain, the Macquarie Marshes and the Gwydir wetlands. Clearing of floodplain trees such as River Red Gum, Coolibah and Black Box, or the clearing of shrubs, especially Lignum, eliminates the nesting sites of many waterbird species. In NSW new vegetation management legislation is being developed and threatened species legislation should now provide better protection to wetland habitat (B Johnson pers. comm.).

## 7.2 Grazing of wetlands

Grazing occurs in some wetlands within the Basin, for instance the Macquarie Marshes and the Gwydir wetlands. This can have an impact since the cattle tend to selectively graze on the more palatable species which tends to reduce the abundance of those species. Heavy grazing can also prevent the regeneration of red gums. However if the grazing is properly managed, and if colonial nesting sites are not disturbed, the impacts on waterbirds can be minimised.

## 7.3 Introduction of exotic species

Foxes, pigs and cats; Both foxes and pigs can have an impact on waterbirds, particularly if they reach colonial nesting sites. In the Macquarie Marshes, pigs have on occasions been reported to be eating young ibis (B Johnson pers. comm.). Kingsford (pers. comm.) reported an incident where pigs destroyed Brolga nests. Feral cats could also be a problem, but they are more likely to be found only around the drier edges of wetlands (B Johnson pers. comm.). Overall, the impact of pigs, foxes and cats on waterbird breeding events (which can involve thousands of birds), is probably only small (R Kingsford pers. comm.).

Introduced fish species; The impact of carp on waterbird species is difficult to determine. They would provide food for fish-eating birds such as cormorants and pelicans (R Kingsford pers. comm.), but any indirect effects (such as increased turbidity of water, uprooting of water plants or competition with native fish species) that carp might have on aquatic ecology, and hence on waterbirds, is not yet fully understood.

Introduced diseases; Currently there are no known introduced diseases having a major impact on waterbird populations (R Kingsford pers. comm.).

Aquatic weeds; Salvinia (*Salvinia molesta*) and Water Hyacinth (*Eichhornia crassipes*) have the potential to choke wetlands and eliminate open water for waterbirds to feed from. Water Hyacinth for instance has been a problem in the Gwydir wetlands (R Kingsford pers. comm.). To date, however, the impact of introduced aquatic plants on waterbirds has probably only been a problem in a small number of wetlands within the Murray-Darling Basin.

Introduced waterbirds - Mallards*;* This is a bit of an unknown quantity, although there has been some studies undertaken around Adelaide to show that cross breeding of native ducks with Mallards is spreading (R Kingsford pers. comm.). However, Kingsford (pers. comm.) suspects that Mallards do not cope very well with the climatic variability of inland Australia, and that they are only a problem locally around cities where people tend to feed ducks.

## 7.4 Waterfowl hunting

Until recently, many species of waterfowl were legally hunted during an open season in all states within the Basin. This now only occurs in Victoria, South Australia and Queensland. Some birds are also shot as pests by farmers, particularly in rice growing areas of southern NSW.

Braithwaite (1975) and Briggs *et al.* (1993) have both reported that hunting, if properly controlled, does not seriously affect waterfowl populations. Kingsford (pers. comm.) suggested that for most species of waterfowl, the effects of river regulation are much more important than the impacts of hunting. However, Braithwaite (1975) suggested that studies by Frith (1959, 1962, 1963) with Grey Teal indicated that during times of drought, when birds are concentrated on a few refuge areas, mortality from hunting can be high. A study on Barren Box Swamp in southern NSW during the 1982 open season (Briggs *et al.* 1983) also supports this view.

Another impact which is related to hunting is the ingestion by waterbirds of lead shot from spent shells. This has been a problem for waterbirds on some wetlands in Victoria and South Australia. (Kingsford *et al.* 1989; Wickson *et al* 1992).

## 7.5 Changes to water quality

Water quality of wetlands has been altered by irrigation, with some becoming more saline (Sharley 1991, Wettin 1991), by nutrients from sewage, fertilisers and stormwater, by pesticides (DWR 1990), and by siltation from altered patterns of land use (Pressey & Harris 1988; Maher 1991).

Effects on waterbirds of increasing salt and nutrient levels in wetlands are not well understood. Converting ephemeral wetlands into evaporation basins for saline water can enhance their value for migratory wading birds (Suttor 1989) but may make them less suitable for other species. High nutrient loads in wetlands increase their value for some ducks, but other waterbirds are likely to be affected negatively (Briggs 1994).

Increased turbidity of water has probably not had a large impact on waterbirds, since wetlands have a very great capacity to filter turbid water and absorb the suspended sediment.

The impacts of waterborne pesticides on wetland birds is not fully understood, although there are occasional reports of bird kills. In the beginning of 1996 there was a kill of about 500 Ibis chicks in the Macquarie Marshes. These birds were contaminated with an agricultural chemical called chlorpyrifos. It appears that the adults brought back contaminated food and this killed all the young birds as well as some of the adults (B Johnson pers. comm.).

Effects of reduced water quality caused by low level releases from large water storages in the upper catchment would have negligible effect on waterbirds since most waterbird habitat is in wetlands many hundreds of kilometres further downstream. As the water spreads out over these shallow wetlands, any reduction in dissolved oxygen or temperature would be quickly eliminated.

## 7.6 Draining of wetlands, construction of levees, channelling of water

Draining of wetlands has been a major problem along the east coast of Australia and might have reduced the number of drought refuges available to waterbirds. In most parts of the Murray-Darling Basin, draining of wetlands has been less common due to the large expense involved, although some wetlands are now being used for lake-bed cropping.

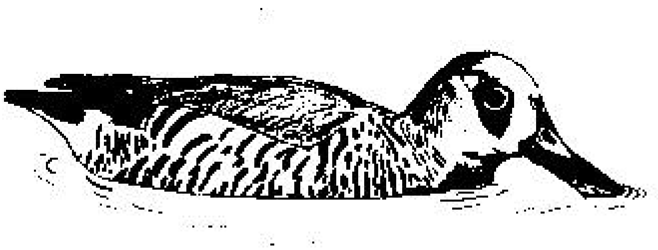
Flood levees have been constructed on the floodplains of many rivers where irrigated crops or towns are located. These levees isolate many small wetlands and billabongs from the many river channel during flooding and thus reduce their suitability as waterbird feeding and breeding areas.

Channelling of water often deprives floodplain wetlands of water during small to medium sized flood events. The Border rivers on the NSW/QLD border for instance, used to have a very complex system of anabranches and flood runners, but with the construction of weirs and regulators, most of the water is now restricted to a few main channels (Kingsford, 1996). Similarly, channelling of water in the Gwydir River has reduced water to wetland areas and hence reduced feeding and breeding habitat for waterbirds (McCosker & Duggin 1992). Another example of the channelling of water is the bypass channel which was constructed around the northern part of the Macquarie Marshes to provide more water downstream for irrigation (B Johnson pers. comm.)..

## 7.7 Other impacts

a) Effect of Climate Change on river flows; CSIRO, NSW National Parks & Wildlife Service and Hassall & Associates are undertaking a project to predict any changes in river flows due to climate change caused by the greenhouse effect (B Johnson pers. comm.). There have been predictions that rainfall might be reduced by up to 10%, and temperature will rise by 2 degrees, which could for instance result in up to a 30% reduction in overall water yield from the Macquarie River Catchment. This could potentially have a major impact on the Macquarie Marshes and hence on waterbird breeding.

b) Habitat loss for migratory waders; Migratory waders fly every year from Australia to breeding grounds in the northern hemisphere. Many of these breeding grounds are in remote places such as Siberia and are not badly threatened at present. However, the loss of coastal habitat at stop-over sites along the migration routes poses the biggest threat to these birds.  This is particularly so in China where there is broadscale filling in of mudflats, and construction of vast ponds for aquaculture.  Hunting of birds at many of the stop-over points throughout South-East Asia also takes a toll, as do human competition for food resources, and harvesting of reed beds (Doug Watkins of Wetlands International pers. comm.; R Kingsford pers. comm.).



Black Swan on nest *(David Eastburn, MDBC)*

Australian Pelicans *(David Eastburn, MDBC)*

# 8. Conclusions and recommendations

## 8.1 Management recommendations

a) Returning to the natural pattern of flow; The best scenario for managing regulated rivers is, if possible, to reflect the natural pattern of flows, particularly in terms of critical parameters such as the season, duration and frequency of floods. For the rivers of the Murray-Darling Basin there is considerable natural variation from year to year in both the floods and low flows, and ideally these variations should also be maintained if the species diversity of these rivers is to be maintained. In the Macquarie Marshes the new water management plan aims to re-introduce a more natural flow regime by allowing rainfall throughout the Macquarie river catchment to influence the nature of flows in the river downstream of the major dams. (NPWS/DLWC 1996).

Along rivers that have a high degree of regulation and water extraction, such as the Murray, flooding of wetlands has been reduced in both duration and frequency. However, it is often not possible to re-introduce a more natural flow regime to the river, and other management options are required. The duration of wetland flooding, for instance, can be artificially extended for a few months by the retention of water using regulators at the entrance to the wetlands. This would be of particular benefit to the egrets, which take the longest time to reach peak breeding following flooding (Briggs *et al.* 1997; Briggs & Thornton, in press). Along sections of the Murray which have artificially high summer flows, these regulators can also be used to ensure that the wetlands are allowed to dry out periodically and thus prevent the death of the red gums through permanent inundation.

b) Season, duration, and water level of floods; Wetlands in the south of the Murray-Darling Basin generally should be flooded in late winter or spring and remain watered for 4 to 18 months. They should not be permanently flooded for longer than two years (Briggs 1990). In the north of the Basin successful waterbird breeding will occur during floods of a similar duration that occur in spring or summer. Sufficient duration of flooding, and the avoidance of sudden drops in water level are the critical factors.

c) Nesting Habitat; Successful breeding will not occur unless there is suitable nesting habitat. This includes floodplain trees such as River Red Gum, Black Box and Coolibah, bushes such as Lignum, and dense stands of rushes, reeds and Cumbungi. Most of this floodplain vegetation depends on a similar flooding and drying cycle that the waterbirds have also adapted to. Floodplain vegetation must also be protected from land clearing for agricultural development, overgrazing by stock and timber harvesting. More specific water management guidelines for the management of River Red Gum wetlands have been presented by Briggs & Thornton (1995).

d) Drought refuges; Another management objective should be to provide refuge areas for waterbirds to use during extended dry periods. This would support residual populations for later recolonisation of breeding areas when the next flood arrives. Refuge areas should be located both inland and along the coast. Inland drought refuges should be located along rivers that are already regulated, unregulated rivers should not be altered for this purpose; they have a more important role of providing the wetting/drying cycle which is so important to the breeding and feeding requirements of many waterbird species.

e) A Basin-wide inventory and management plan for wetlands; NSW National Parks & Wildlife Service are currently undertaking a project in which all wetlands within the Basin are being mapped using Landsat Imagery and loaded onto a GIS (R Kingsford pers. comm.). Ultimately this inventory should also provide information on the loss of wetlands within each catchment (both as the loss in area and the loss of habitat types), and the potential threats being faced by each wetland. Once this inventory is complete, a Basin-wide management plan for wetlands could be produced. This plan would allow a co-ordinated approach to wetland management and would help ensure that suitable wetland habitats are preserved (or restored) for all waterbird species that use the Murray-Darling Basin. More specific management plans for wetlands of particular importance to waterbirds could then be produced. These would include details on water management (such as the construction of regulators), vegetation management (such as; controls on grazing and timber harvesting, weed control, and fire management), protection of waterbird breeding sites, controls on agricultural developments and long term monitoring strategies.

This Basin-wide or regional approach is an essential aspect of wetland (and therefore waterbird) management. Inevitably, wetlands will be managed for a variety of purposes, and the aim should be to manage for a mosaic of wetlands with different water regimes. Some wetlands have been converted into permanent water storages, and these can provide drought refuges for some species. Other wetlands can be manipulated to retain a central area of water to partly compensate for the reduced duration of flooding which has been caused by water extraction for irrigation. And finally, many of the wetlands within the Basin should be allowed to dry out entirely between floods to reflect the natural wetting and drying cycles of these systems. A Basin-wide approach to wetland management will ensure that suitable habitat exists for the feeding and breeding requirements of all waterbird species.

f) Save the remaining unregulated river systems; In many parts of the Murray-Darling Basin, water extraction has reached a level where there is a major impact on the natural flow regime of the rivers. Although there is scope to better manage these highly regulated rivers, there is little chance of them returning to a state resembling their natural condition. There are however some rivers within the Basin, in particular those rivers in the north-west such as the Paroo and Warrego rivers that are relatively undeveloped and are important breeding and feeding grounds for many waterbirds. To ensure the survival of these waterbirds, it is essential that these rivers remain unregulated and free of diversions for irrigation so that they can continue to operate through the natural cycle of floods and droughts. Other unregulated rivers outside the Basin, such as the Cooper Creek system also form important breeding areas and should not be developed.

## 8.2 Long term monitoring

a) The need for long term monitoring; Because we are dealing with species and ecological systems that have huge natural variability, to actually start to detect long term changes is really quite difficult, and will only be noticeable over a time frame of 20-50 years. For instance on the Macquarie Marshes over a 10 year period (1983 to 1993), the number of waterbirds sighted during aerial surveys fluctuated between 2,300 and 88,600 depending on the flooding both within the Marshes and throughout eastern Australia. Therefore any attempt to monitor waterbird populations needs to be undertaken over a period of 20-50yrs. If this is not possible, the monitoring program should at least use techniques that are accurately described and can be easily repeated by other researchers in 10, 20 and 50 yrs time.

b) Indicator species for monitoring programs; Most monitoring programmes cannot afford to monitor all waterbird species. Generally, a smaller number of key indicator species are selected. The indicator species which are selected should be sensitive to changes in the environment (such as changes to the flow regime) and should also be easy to monitor.

NSW National Parks & Wildlife Service are using the colonial breeding waterbirds as key indicator species in the Macquarie Marshes. They were selected partly because they are easier to observe (and count) than most other waterbirds, but also because they have specific breeding needs in terms of; the timing, depth and duration of flooding, and the need for specific vegetation types for nesting (B Johnson pers. comm.). The two species of particular interest are the Straw-necked Ibis and the Intermediate Egrets. The Straw-necked Ibis have very specific requirement in terms of a constant water level around their nests and the Intermediate Egrets need a longer flood time than most of the other colonial breeders. So if these two species are successful at breeding then other colonial species (such as Glossy Ibis, Australian White Ibis, Great Egret, Little Egret, Cattle Egret, Rufous Night Heron and cormorants) as well as most non-colonial breeders, are also likely to be successful. Great Egrets would also be a useful indicator, since they require the longest flood duration for successful breeding. However they only breed at a handful of sites in the Basin and hence cannot be widely used (R Kingsford pers. comm.).

Kingsford (pers. comm.) proposed that a good indicator of wetland health is the total abundance of waterbirds combined with the species diversity. Different waterbird species tend to indicate different features of a wetland and a high species diversity of waterbirds indicates that a diverse range of habitats is available within the wetland. The presence of large numbers of some waterbirds will indicate a large invertebrate population whereas others might indicate large fish populations or macrophyte abundance. Although total abundance and diversity at a particular site might be useful for measuring the health of that wetland, it does not provide a clear picture of waterbird health on a Basin-wide or national scale. Many of the waterbird species are highly mobile and the abundance at a particular site will fluctuate by orders of magnitude from year to year (R Kingsford pers. comm.). For this reason, the technique being used to assess waterbird health on a national scale is to conduct aerial surveys of abundance and diversity across eastern Australia on a yearly basis (see for example Kingsford *et al.* 1993).

## 8.3 Future research priorities

Some research priorities for the conservation of waterbirds in the Murray-Darling Basin are listed below;

1. The biophysical processes in wetlands are driven by the water regime and it is important that we understand the relationships between the two if we are to gain a full understanding of how wetlands function. This knowledge is essential for both wetland and waterbird management. Further research should continue to investigate the effects of changed river flows on wetland biota. Specific topics might be;
    - productivity, biodiversity and carbon cycles of lakes and billabongs with different flood regimes, including the effects of full drying, partial drying and permanent water
    - effects on the biophysical processes and biodiversity of rapid rises and falls of the water level

   Unregulated 'pristine' rivers could be used to determine how these processes operated under natural flow conditions, and this information would assist in determining the best management practices for regulated systems.

2. There is a need for studies into wetland conservation on private land, and how private landholders can be encouraged to protect wetland habitat on their properties. A significant portion of wetland habitat in the Murray-Darling Basin is on private property, and hence the preservation of this land is an important priority for waterbird survival.

3. There is very little information on which to base management decisions about artificially inundated wetlands. There is a need for studies of abundance and biomass of biota, presence/absence of species or taxa, and species diversity in wetlands that have and have not been artificially inundated. This should include investigations of how abundance and diversity of plants and animals can be influenced by applying different water regimes to these artificially inundated wetlands (eg seasonal and steady rises and falls in water level compared with sudden rises and falls). This information would allow better management of wetlands whose primary use is for water storage, recreation etc (ie not conservation).

4. Floodplain and riparian <u>woodlands</u> are very important waterbird breeding habitat and a better understanding of these areas is an important research priority. Research is needed on: (i) management of these communities for conservation of biodiversity; and (ii) understanding how riparian and floodplain woodlands function in the landscape (eg in nutrient control and cycling, organic carbon dynamics etc.). Management of woodland communities for biodiversity includes management of tree structure and vegetation understory as well as management of flooding regimes. Research is needed to identify how woodland structure affects their biodiversity, as well as how biodiversity in riparian and floodplain woodlands relates to water regimes.

5. There is increasing pressure to develop the remaining unregulated rivers within the Murray-Darling Basin, such as the Paroo and Culgoa for irrigated agriculture. There needs to be a study to determine the relative importance of these rivers (and their associated wetlands) for waterbird breeding and feeding. This should be followed up by predictions of the impact on waterbirds (on a national scale) if the development of these river systems was allowed to occur.

6. Other research topics are;

   - Compare the effects of winter-spring flooding with summer-autumn flooding on breeding activity of waterbirds in the southern M-D Basin.

   - Ascertain what the relationships are, if any, between length of drought and condition of waterbirds on permanent water bodies.

   - Investigate whether some wetlands provide better breeding or survival habitat than others, and if so, which ones.

   - Investigate some of the more cryptic and less studied species like crakes, rails, and bitterns, and determine; their water requirements for successful breeding; how to maintain suitable habitat for them; and how to ensure their survival during dry periods.

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# Appendix 1

## Species observed in the Murray-Darling Basin Waterbird Project (co-ordinated by the RAOU)

*(information obtained from Phil Straw, RAOU office, Sydney, March 1997. This list includes rare vagrants)*

### Grebes (Podicipedidae)

Great Crested Grebe
Australasian (Little) Grebe
Hoary-headed Grebe

### Pelicans (Pelecanidae)

Australian Pelican

### Cormorants (Phalacrocoracidae)

Great Cormorant
Little Black Cormorant
Little Pied Cormorant
Pied Cormorant

### Darters (Anhingidae)

Darter

### Herons, Egrets, Bitterns, Night-herons (Ardeidae)

Little Egret
Intermediate Egret
Great Egret
White-faced Heron
White-necked (Pacific) Heron
Rufous (Nankeen) Night-heron
Little Bittern
Black Bittern
Australasian Bittern
Cattle Egret

### Storks (Ciconiidae)

Black-necked Stork (Jabiru)

### Ibis, Spoonbills (Plataleidae)

Glossy Ibis
Australian White Ibis (Sacred Ibis)
Straw-necked Ibis
Royal Spoonbill
Yellow-billed Spoonbill

### Ducks, Geese, Swans (Anatidae)

Cape Barren Goose
Magpie Goose
Cotton Pygmy Goose
Green Pygmy Goose
Maned Duck (Wood Duck)
Black Swan
Wandering Whistling-duck
Plumed Whistling-duck
Australian Shelduck (Mountain Duck)
Pacific Black Duck
Chestnut Teal
Grey Teal
Australasian Shoveler
Pink-eared Duck
Freckled Duck
Hardhead (White-eyed Duck)
Blue-billed Duck
Musk Duck
Muscovy Duck
Mallard
Domestic Duck hybrids
Northern Shoveller
Domestic Goose

### Rails, Crakes, Swamphens, Moorhens, Coots (Rallidae)

Lewin's Rail
Buff-banded Rail
Australian Spotted Crake
Baillons (Marsh) Crake
Spotless Crake
Black-tailed Native-hen
Dusky Moorhen
Purple Swamphen
Eurasian Coot

### Cranes (Gruidae)

Brolga

### Jacanas (Jacanidae)

Comb-crested Jacana

### Painted Snipe (Rostratulidae)

Painted Snipe

### Oystercatchers (Haematopodidae)

Pied Oystercatcher
Sooty Oystercatcher

### Plovers, Dotterels (Charadriidae)

Red-kneed Dotterel
Masked Lapwing
Grey Plover
Lesser (Pacific) Golden Plover
Hooded Plover
Double-banded Plover
Red-capped Plover
Black-fronted Plover (Dotterel)
Little Ringed Plover

### Curlews, Snipe, Sandpipers, Stints (Scolopacidae)

Little Curlew
Black-tailed Godwit
Bar-tailed Godwit
Wood Sandpiper
Common Sandpiper
Common Greenshank
Marsh Sandpiper
Curlew Sandpiper
Red-necked Stint
Sharp-tailed Sandpiper
Great Knot
Sanderling
Latham's (Japanese) Snipe
Long-toed Stint
Pectoral Sandpiper
Ruff

### Avocets, Stilts (Recurvirostridae)

Black-winged Stilt
Banded Stilt
Red-necked Avocet

### Gulls, Terns (Laridae)

White-winged Tern
Whiskered Tern
Caspian Tern
Gull-billed Tern
Crested Tern
Little Tern
Fairy Tern
Silver Gull

### Others birds associated with wetlands

Swamp Harrier (Marsh Harrier)
White-bellied Sea Eagle
Whistling Kite
Osprey
Azure Kingfisher
Little Grassbird
Tawny Grassbird
Clamorous Reed-warbler