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## BREEDING OF MANED DUCK AND OTHER WATERBIRDS ON EPHEMERAL WETLANDS IN NORTH-WESTERN NEW SOUTH WALES

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Ephemeral wetlands on Nocoleche Nature Reserve in north-western New South Wales flooded and dried three times between October 1985 and October 1988. Forty-nine species of waterbirds used the wetlands. Maned Ducks and Grey Teal bred in each of these flooding events, and laid at all times of the year except late summer. Other waterbirds, including Black Swans, Pacific Black Ducks, Australasian Shovelers, Pink-eared Ducks, White-faced Herons and grebes, bred during one or two of the flooding events. Some Maned Ducks bred in spring on permanent water. The Paroo River flooded four times during the study, but its overflow areas were not filled long enough to allow most waterbirds to breed.

### INTRODUCTION

Although the semi-arid, north-western region of New South Wales can be dry for long periods, it provides large areas of waterbird habitat when rains come. Flooding rivers and creeks fill associated overflow lakes and swamps, the many claypans and depressions fill from local runoff, and waterbirds move into these newly filled wetlands. An opportunity arose to observe how and when waterfowl (Anatidae) and other waterbirds use these ephemeral wetlands at Nocoleche Nature Reserve (Fig. 1) between April 1985 and October 1988. The specific aims of the study reported here were, firstly, to determine how and when waterbirds, particularly waterfowl, used the wetlands on Nocoleche Nature Reserve, and secondly, to determine the relative effects of time of year and wetland dynamics on waterbird nesting patterns in north-western New South Wales. This study was carried out in association with a study on the breeding ecology of Maned Ducks, which will be reported later.

### STUDY AREA

Nocoleche is a 74 728 ha Nature Reserve, 190 km west of Bourke on the Paroo River (29°52'S, 144°10'E) (Fig. 1). It covers sections of the Kulkynne Creek, Cuttaburra Creek and Paroo River floodplains, their numerous channels and swamps, and an extensive sandplain which contains many small claypans and depressions (Fig. 2a). The climate is one of high summer temperatures (to 45°C), warm winters, low relative humidity and extremely variable rainfall with an annual average of about 280 mm.

The 100 sq. km study area within the Reserve (Fig. 2b) covered a 7 km stretch of the Paroo River with its associated channels and swamps, and a 57 sq. km portion of the sandplain containing over 200 depressions a few hundred metres apart. These two wetland types, the floodplain swamps and the depressions on the sandplain, are parts of two distinct wetland systems defined by Goodrick (1984), and named 'Cuttaburra' and

'Nocoleche' respectively. The habitats of the two wetland systems within the study area are described in Table 1.

The Paroo River floods from rains received in its catchment in southern Queensland, independently of local rainfall. It then spreads from its permanent main channel into the shallow distributory channels and swamps of the 'Cuttaburra' wetland system (Table 1, Fig. 2b). As floods move downstream, floodwaters drain out of the overflow wetlands back into the river, leaving the occasional almost permanent waterhole (Fig. 2b). By contrast, the depressions of the 'Nocoleche' wetland system fill by runoff from local rainfall in their individual catchments, and dry by evaporation. They range greatly in size (Fig. 2b), soil type and vegetation (Table 1). Hard, flat claypans

TABLE 1

Wetland habitats in the study area on Nocoleche Nature Reserve (alter Goodrick 1984).

**CUTTABURRA WETLAND SYSTEM:** Shallow distributory channels and overflow swamps of major streams frequently inundated by regional runoff. Water fresh and turbid; soils are grey cracking clays, often gilgaied. Comprises:

- (a) Main river channel, and near-permanent waterholes fringed by Coolibah *Eucalyptus microtheca*, River Red Gum *E. camaldulensis* and River Cooba *Acacia stenophylla*, understoried by Lignum *Muehlenbeckia cunninghamii*, sedges and forbs. Both support little aquatic vegetation.
- (b) Shallow channels and swamps supporting scattered to dense stands of lignum, often overstoried and fringed by Coolibah, River Red Gum, River Cooba and Yapunyah *Eucalyptus ochrophloia*. Dense growth of Common Nardoo *Marsilea drummondii*, sedges and other forbs during and after prolonged flooding.

**NOCOLECHE WETLAND SYSTEM:** Small pans and swamps in sandplains frequently inundated by local runoff. Often fringed by Black Box *Eucalyptus largiflorens* and/or Poplar Box *E. populnea*. Common Nardoo and other aquatic plants grow when flooded for long enough. Ranges from:

- (a) Small claypans of red, sandy clay-loam either devoid of vegetation or with varying densities of Canegrass *Eragrostis australasica*, through a variety of intermediate forms to:
- (b) Swamps of gilgaied, cracking grey clays up to 300 m or more across, vegetated by scattered Lignum (often Spiny Lignum *Muehlenbeckia horridus*), sedges, grasses and forbs.

retain surface water from minor rainfalls, but depressions with more gilgaied and cracked loamy surfaces absorb much more water than the claypans before beginning to fill. Some 'Nocoleche' wetlands contain artificially dug ground tanks, which retain water for longer than the surrounding wetland. Consequently the wetlands vary in their depth and longevity of flooding.

Other factors affecting the occurrence and duration of flooding in the 'Nocoleche' wetlands are the amount of runoff (determined by the amount, intensity and frequency of rainfall) and evaporation rates (determined by temperature, wind and relative humidity). The swamps dry much more quickly in summer than in winter. Some of the larger depressions in the 'Nocoleche' system, such as Momba Swamp and Pied Stilt Swamp (Fig. 2b), are filled by intermittent streams which drain a large stony plateau to their south-west. These swamps often retain water for several months after heavy or prolonged rain.

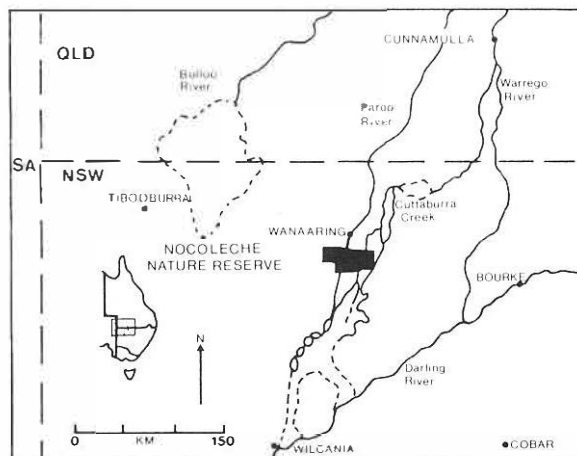


Figure 1. Location of Nocoleche Nature Reserve (solid black area) in relation to the river systems of north-western New South Wales. Dashed lines indicate overflow areas. Detail of Nocoleche N.R. is given in Figure 2a.

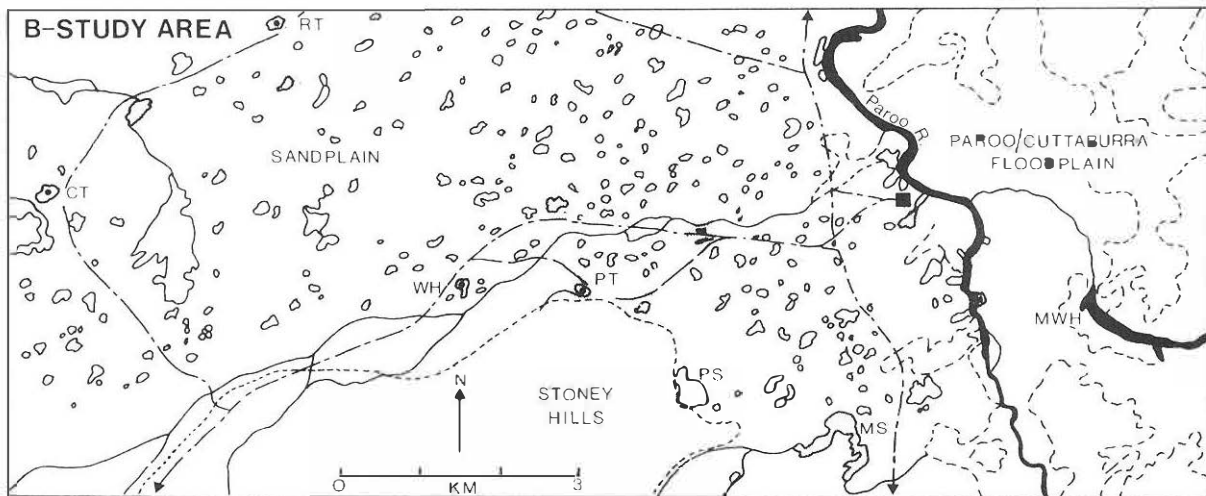
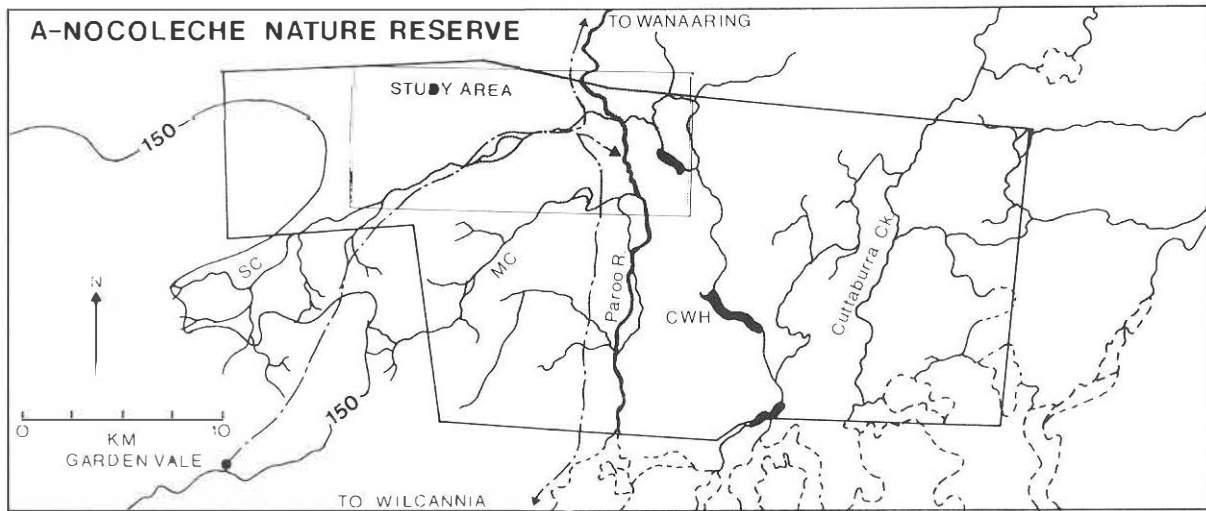


Figure 2a. Nocolèche Nature Reserve showing hydrology. The study area is shaded; Nocolèche homestead is indicated by the solid black triangle in the shaded area; contour is expressed in metres above mean sea level; SC = Sandy Creek; MC = Momba Creek; CWH = Corellia Waterhole.

Figure 2b. The study area showing wetlands of the 'Nocolèche' and 'Cuttaborra' systems. 'Nocolèche' wetlands are to west of the Paroo River. Shading denotes study wetlands monitored regularly; solid black areas indicate permanent or semi-permanent waters; the solid black square denotes Nocolèche homestead. The broken line around the stoney hills indicates their approximate edge; the broken lines near the Paroo River denote its overflow areas ('Cuttaborra' wetlands). CT = Claypan Tank; RT = Ram Tank; WH = White Horse Tank; PT = Peka Tank; PS = Pied Stilt Swamp; MS = Momba Swamp, and MW = Mimonite Waterhole.

Both the 'Cuttaburra' and 'Nocoleche' wetlands can fill simultaneously, from widespread rain falling locally, as well as in the Paroo River catchment. When the ephemeral wetlands of both systems dry, water remains only in the river channel, in three waterholes (which are permanent except in severe droughts) and in four semi-permanent ground tanks (Figs. 2a, b). In this paper, Nocoleche Nature Reserve (or N.R.) refers to the area shown in Fig. 2a. 'Nocoleche' wetlands or the 'Nocoleche' system refer to wetlands of the type defined by Goodrick (1984), described in Table 1, and located to the west of the Paroo River in the study area on Nocoleche N.R. (Fig. 2b).

### METHODS

Eleven field trips were made to Nocoleche Nature Reserve between mid-April 1985 and mid-October 1988. Most were about two weeks long, but field trips of up to one and a half months were made during major flood events. Timing and duration of field trips in relation to local rainfall and wetland flooding are shown in Figure 3. The Paroo/Cuttaburra floodplain to the east of the Paroo River (Fig. 2b) was inaccessible after heavy rain. Observations on waterbird activity in this area were therefore generally not possible immediately after rain.

Only the main study wetlands indicated by shading in Figure 2b were regularly monitored for waterbird numbers and signs of breeding (nests, young). Maned Ducks also were cage trapped (McNally and Falconer 1953) at these sites, and individually marked with metal bands and with colour bands. Occasionally Pacific Black Ducks and Grey Teal were trapped and banded, but were not colour marked. All trapped ducks were checked for notched tail feathers and all females were inspected for signs of laying (eggs in abdomen or open pelvis, pelvic bone spread >15 mm) or incubating (presence of brood patch). Ducklings of Maned Ducks were aged following Kingsford (1986). Ducklings of other ducks were aged from their size relative to their size at fledging, compared with their known or estimated fledging times (Johnsgard 1978; Fullagar *et al.* 1988).

Following Eisenmann (1965), 'juvenal' refers specifically to ducks in their first plumage after the downy stage, whereas 'juvenile' refers to

young ducks with either juvenal or adult plumage but still with notched tail feathers. In Maned Ducks 'juvenal' indicates an age of from six weeks to about three months (Kingsford 1986). Notched tail feathers persist in the species for about a further month (Briggs, unpubl. data), and thus juveniles are under four months old.

Rainfall records were taken at Nocoleche N.R. homestead. The few missing values were obtained from the Bureau of Meteorology's records for Wanaaring (17 km distant). The annual mean rainfall used for the study area was the mean of the average annual rainfalls for Bourke and Tibooburra, obtained from Bureau of Meteorology.

Scientific names of species mentioned in the text are given in Tables 1 and 2.

### RESULTS

#### *1. January 1986: a short summer flood after a dry year.*

The study began during a dry autumn and winter (Fig. 3). Only 67 mm of rain fell in 1985 before August. There were showers in August and late October, but they were too scattered to fill the wetlands. In early October the only surface water in the study area (Fig. 2b) was in the river channel, one waterhole and two ground tanks. There were only about 30 Maned Ducks and a few other waterbirds present. None of the 13 female Maned Ducks trapped in early October were juveniles or showed evidence of breeding, and no broods or juvenals were observed. Heavy rain began on 3 November, and the total rainfall from then to the end of December 1985 was 143 mm (Fig. 3). All the depressions in the 'Nocoleche' system were filled, providing a network of waterbird habitats throughout the sandplain (Fig. 2b). The total rainfall for 1985 was 253 mm (Fig. 3).

About 500 Maned Ducks, and many other waterbirds, were present in the study area in mid-January 1986. Of 38 female Maned Ducks trapped in mid-January, 11 had recently been incubating eggs. At least 20 Maned Duck broods were seen on the 'Nocoleche' wetlands during this field trip (Fig. 3). They ranged in age from one to six weeks. This places hatching between mid-December and mid-January, so laying began in early November after the wetlands filled (Fig. 4a).

TABLE 2

Habitats and breeding times of waterbirds recorded in the study area on Nooleche Nature Reserve. \* = recorded; b = recorded breeding; D = depressions; LD = large depressions only; R = river; T = ground tanks (regularly used); W = waterholes. Numbers refer to flooding/breeding events as numbered in the headings in the text.

Species	Habitat	Flooding/breeding events				
		1	2	3	4	5
Hoary-headed Grebe <i>Polyocephalus polyocephalus</i>	LD, T	*	*			b
Australasian Grebe <i>Tachybaptus novaehollandiae</i>	I, D, T	*	b		*	b
Australian Pelican <i>Pelecanus conspicillatus</i>	I, D, R, W	*	*	*	*	*
Darter <i>Anhinga melanogaster</i>	I, D, W	*				*
Great Cormorant <i>Phalacrocorax carbo</i>	LD, R, W	*				*
Pied Cormorant <i>Phalacrocorax varius</i>	LD, R, W	*				*
Little Black Cormorant <i>Phalacrocorax sulcirostris</i>	I, D, R, W	*	*	*		*
Little Pied Cormorant <i>Phalacrocorax melanoleucos</i>	LD, R, W	*	*			*
Pacific Heron <i>Ardea pacifica</i>	D, R	*	*	*	*	*
White-faced Heron <i>Ardea novaehollandiae</i>	D		b	*	*	b
Great Egret <i>Egretta alba</i>	D, R	*	*	*	*	*
Little Egret <i>Egretta garzetta</i>	D		*			*
Intermediate Egret <i>Egretta intermedia</i>	D	*				*
Rufous Night Heron <i>Nycticorax caledonicus</i>	D, R	*	*		*	*
Glossy Ibis <i>Plegadis falcinellus</i>	D	*	*			*
Sacred Ibis <i>Threskiornis aethiopicus</i>	LD	*	*			*
Straw-necked Ibis <i>Threskiornis spinicollis</i>	D	*	*			*
Royal Spoonbill <i>Platalea regia</i>	D, R, W	*	*			*
Yellow-billed Spoonbill <i>Platalea flavipes</i>	D, R, W	b	*	*	b	b
Plumed Whistling-Duck <i>Dendrocygna eytoni</i>	flying					*
Black Swan <i>Cygnus atratus</i>	LD					b
Freckled Duck <i>Stictonetta naevosa</i>	I, D, W		*			
Pacific Black Duck <i>Anas superciliosa</i>	D, R, W	b	*			b
Grey Teal <i>Anas gibberifrons</i>	D, R, W, T	b	b	*	*	b
Australasian Shoveler <i>Anas rhynchos</i>	D, R	*	*	*		b
Pink-eared Duck <i>Malacorhynchus membranaceus</i>	D, R, W, T	*	*			b
Hardhead <i>Aythya australis</i>	LD, R, T	*	*			*
Maned Duck <i>Chenonetta jubata</i>	D, R, W, T	b	b	*	b	b
Baillon's Crake <i>Porzana pusilla</i>	D					*
Australian Crake <i>Porzana fluminea</i>	D	*	*			
Black-tailed Native Hen <i>Gallinula ventralis</i>	I, D, R, W	*	*			b
Eurasian Coot <i>Fulica atra</i>	LD		*			*
Brolga <i>Grus rubicundus</i>	D	*	b			b
Painted Snipe <i>Rostratula benghalensis</i>	LD		*			
Masked Lapwing <i>Vanellus miles</i>	D, T	*	b	*		b
Banded Lapwing <i>Vanellus tricolor</i>	D	*	*			*
Red-kneed Dotterel <i>Erythrogonys cinctus</i>	D	*	*			b
Black-fronted Plover <i>Charadrius melanops</i>	D, R, W, T	*	b	*	*	b
Black-winged Stilt <i>Himantopus himantopus</i>	D	*	*			b
Red-necked Avocet <i>Recurvirostra novaehollandiae</i>	D	*	*			*
Wood Sandpiper <i>Tringa glareola</i>	I, R		*			
Common Sandpiper <i>Tringa hypoleucos</i>	D		*			
Greenshank <i>Tringa nebularia</i>	LD		*			*
Marsh Sandpiper <i>Tringa stagnatilis</i>	LD		*			*
Snipe <i>Gallinago</i> sp.	D		*			
Sharp-tailed Sandpiper <i>Calidris acuminata</i>	D		*			*
Silver Gull <i>Larus novaehollandiae</i>	I, D	*	*			*
Whiskered Tern <i>Chlidonias hybridus</i>	LD	*	*			*
Gull-billed Tern <i>Gelochelidon nitroica</i>	I, D	*	*			
Total breeding		4	8	0	2	16

The exception was one brood fledged on 10 January, which must have been started prior to the rain in early November (assuming incubation time of 34 days, Briggs unpubl. data, fledging time of 56 days, Kingsford 1986, and one lapsed day per egg laid). Ten Grey Teal broods were seen in January, ranging in age from about two to six weeks. Their ages place the period of laying between early November and the beginning of December (assuming incubation time of 28 days, fledging time of 55 days (Fullagar *et al.* 1988), and one lapsed day per egg laid). Two young Pacific Black Duck broods were also seen in mid January. The other waterbirds which bred in January 1986 are listed in Table 2.

January 1986 was hot and dry, with only 2.5 mm of rain falling during the month. The wetlands were nearly dry by the end of January, so they had provided waterbird habitat for less than three months. No rain had fallen by the next trip, which commenced in late April 1986 (Fig. 3). Waterbirds by then had dispersed, except for a few Maned Ducks which were on the river and Mimonie Waterhole (Fig. 2b).

## 2. October-November 1986: a spring and summer flooding.

A succession of wet months started with heavy rain in early and late July 1986 and in late September, following a dry autumn (Fig. 3). The cumulative total for July, August and September was 155 mm. Observations and trapping started in mid October 1986 when all 'Nocoleche' wetlands in the study area (Fig. 2b) were full. Water in the smaller depressions lasted to late November, and in the larger ones until December. One river rise in late November inundated low 'Cuttaburra' areas close to the main channel, but contributed little to waterbird habitat.

Forty-two species of waterbirds were observed between mid October and late November 1986. Of these, at least eight species were breeding (Table 2). The flooded depressions of the 'Nocoleche' system supported flocks of Grey Teal and Maned Ducks, and smaller groups of Pacific Black Ducks, Pink-headed Ducks, Freckled Ducks, Australasian Shovelers and Hardheads. Of 49 female Maned Ducks trapped in October and

November 1986, eight were laying or incubating. Nineteen broods of ducklings of Maned Ducks were seen during the same period. Maned Ducks began laying in late August, and continued until early November (Fig. 4b). Most clutches were laid by the end of September. Most broods hatched in October and fledged in late November. Grey Teal also bred in late 1986, but in lower numbers and later than Maned Ducks. The two nests found and the ages of the four broods seen indicate that laying began in late September, with broods hatching in early November, and fledging in mid December. This puts the peak laying time of Grey Teal after wetlands were topped up in September (Fig. 3), and about three weeks later than that of Maned Ducks. Australasian Grebes, Black-fronted Dotterels, Brolgas, Masked Lapwings and White-faced Herons were recorded incubating in late October and early November 1986 (Table 2).

By late November the wetlands were drying back quickly (Fig. 3), and all duck numbers were low. Momba Swamp was reduced to a string of pools, but Pied Stilt Swamp still had large areas of open water and flooded sedge. Most remaining ducks congregated there. By mid January virtually all the ephemeral wetlands in the study area were dry (Fig. 3). Water remained only in the river channel, Mimonie Waterhole and the ground tanks. Only small numbers of Maned Ducks (many of which were juvenals) and other waterbirds were present. A total of 220 mm of rain fell in 1986 (Fig. 3).

## 3. March 1987: an autumn river flood with no local rain.

Heavy rain in the catchment of the Paroo River in southern Queensland sent floodwaters downstream to Nocoleche N.R. in early March 1987. Away from the river there was no water except in the ground tanks. On 1 March the river was still within its channel and no ducks were present. By 5 March the flood peak was at the New South Wales border, and at Nocoleche Nature Reserve the channels and lignum swamps of the 'Cuttaburra' system were flooding adjacent to the river. Small numbers of Maned Ducks appeared, feeding on seedheads of flooded sedges, lignum flowers and floating matter.

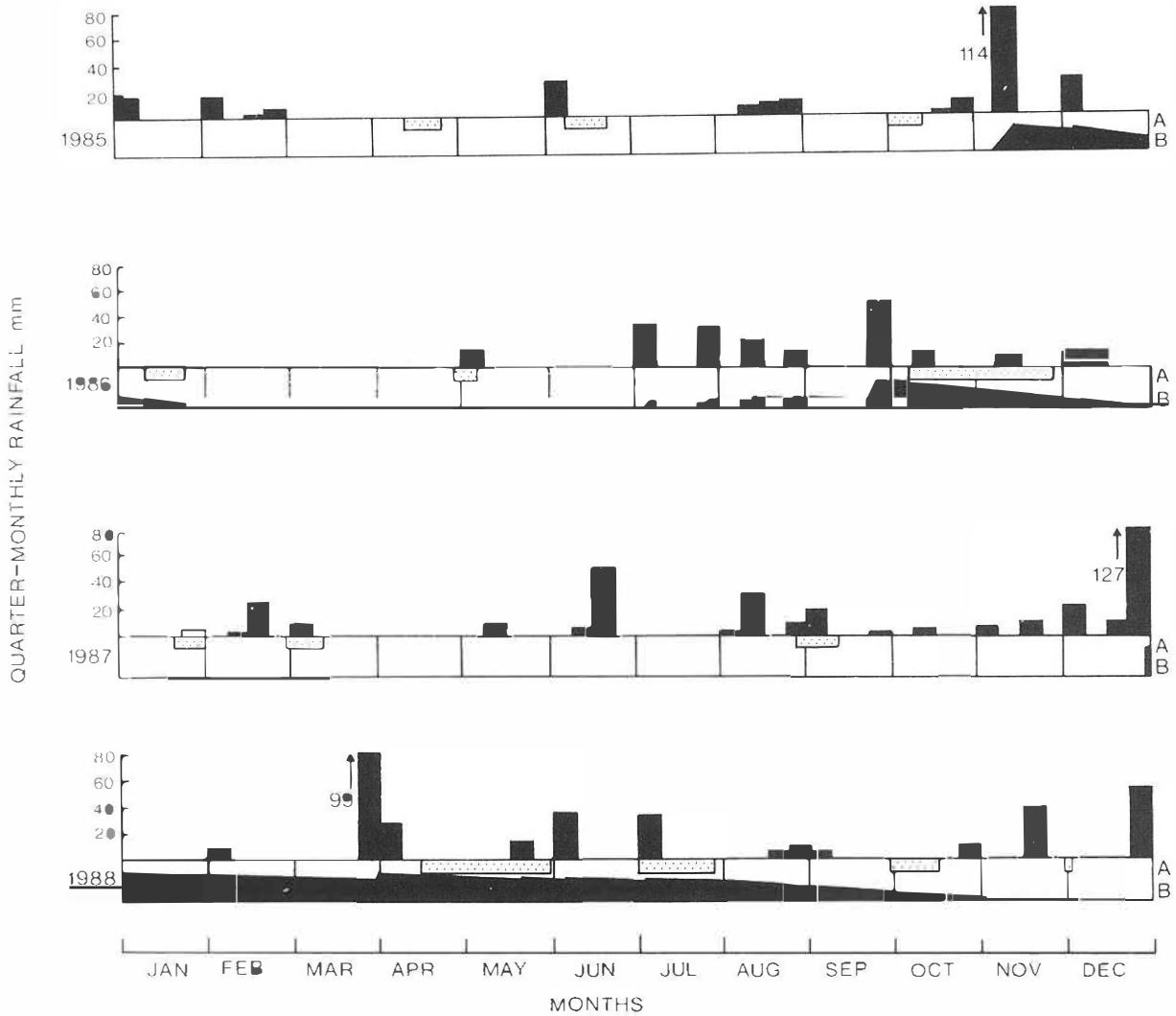


Figure 3. Rainfall (mm) (above line, solid black) for each quarter of the month during the four years of the study, in relation to periods of field observations (A, below line, stippled), and in relation to the amount of water in the 'Nocoleche' wetlands (B, below line, solid black) in the study area.

The flood peaked at Nocoleche N.R. on 10 March. Large areas of lignum, cooba woodland and coolibah/yapunyah woodland of the 'Cuttaburra' system were inundated, extending in places up to 1 km from the river channel. Maned Duck numbers stabilized after 8 March at a density of about 27 per square kilometre of flooded country. Grey Teal were present in lower numbers, and a small group of Australasian Shoveler was recorded once.

Maned Ducks were paired and vocal, and some prospecting of tree holes in the 'Cuttaburra' system was observed, but none of the ten females trapped on 9 or 10 March showed signs of laying. As the flood peak moved downstream, water gradually drained back into the river, out of the flooded areas. The river had returned to normal level by early April, so the influence of the flood lasted less than one month and did not result in breeding of any waterbirds (Table 2).

*4. September 1987: a spring with no wetland flooding.*

Intermittent rain in June and August 1987 (Fig. 3) provided enough moisture for growth of dry-land vegetation during the spring. The rain was insufficient to flood wetlands for long, and by late August the only surface water west of the Paroo River (Fig. 2b) was in the ground tank at Claypan Tank. There were a few ducks on the river, one pair of Maned Ducks on Mimonic Waterhole, and a few pairs (usually four) of Maned Ducks at Claypan Tank (Fig. 2b). These ducks at Claypan Tank fed on new growth on rain-dampened ground close to the tank, and returned to the tank for security, daytime loafing and roosting at night.

Most of the Maned Ducks on Claypan Tank bred in September 1987. On 1 September a pair was seen with a two week old brood of four ducklings. The female, which was colour banded, bred regularly on this tank (see below). Of the seven females trapped in the first half of September, two were laying and three were incubating. Figure 4e indicates the timing of breeding of Maned Ducks in 1987.

Except for Yellow-billed Spoonbills nesting on the river (which was flowing at a high level, though not flooding into associated wetlands), no other species of waterbird was recorded breeding in 1987. The total rainfall for January to November 1987 was 198 mm, with 168 mm falling in December 1987 (Fig. 3).

*5. April-July 1988: a late summer and autumn flooding.*

After being dry for a year the wetlands of the 'Nocoleche' system filled again at the end of December 1987, when 127 mm of rain fell in one day. More rain fell in February 1988, and during the following autumn and winter (Fig. 3). The 'Nocoleche' wetlands in the study area thus provided waterbird habitat from late December 1987 to early November 1988, a period of over ten months. Observations and trapping began in April 1988 when the wetlands were the deepest

and most extensive they had been during the study (Fig. 3). The Paroo River also flooded into all its overflow areas in April, but returned to its main channel by early May. It rose to an even higher level in July, and flooded out into the 'Cuttaburra' wetlands again. Forty species of waterbirds were recorded in the study area in the second half of April and in July 1988, of which 16 bred (Table 2). The breeding times and habitats of the waterbirds which bred in 1988 are summarised in Table 3.

Maned Ducks and Grey Teal bred from mid and early April respectively to October 1988 (Figs 4d, e). The first laying Maned Duck was captured on 24 April and the last on 9 October. Newly hatched broods were observed from early July to late September. The ages of young Maned Ducks in October ranged from two week old ducklings, through more advanced ducklings and flying juvenals, to juveniles over three months old. The first brood of young (<7 days) ducklings of Grey Teal was seen on 17 May. The absence of newly hatched broods of Grey Teal in July (Fig. 4e), and the two distinct age classes of young Teal in early October (<3 weeks old and fully fledged), indicated that there were two major periods of Grey Teal breeding in 1988 (Table 3).

Of three Pink-eared Duck pairs in the study area in 1988, at least two successfully reared broods. They laid at the same time as the first Grey Teal, and had broods of newly hatched ducklings in late May (Table 3). The two broods of Pacific Black Duck were seen much later (Table 3). The first brood was less than two weeks old when seen in early July, which places the commencement of Black Duck laying in the latter half of May. The age of the one duckling of Australasian Shoveler seen (in mid July), places the beginning of incubation in mid May (assuming a six to eight week fledging time, Johnsgard 1978). Three pairs of Black Swans nested on the two larger wetlands (Pied Stilt and Momba Swamps) in 1988. They laid in the second week of May (Table 3), and successfully raised two broods of cygnets. Two pairs of Brolgas also nested on these two wetlands, and one on a smaller, shallow canegrass swamp. Eggs were being incubated in mid May (Table 3), but the Brolga nest on Pied Stilt Swamp was preyed upon. A new nest with eggs was found there in



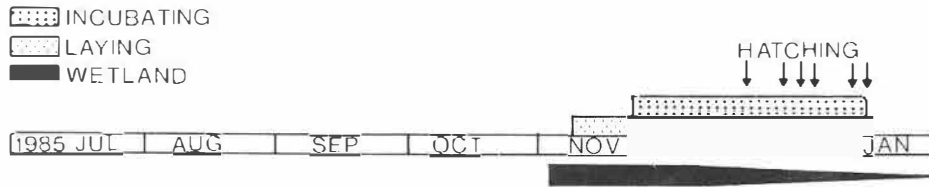


Fig. 4(a)

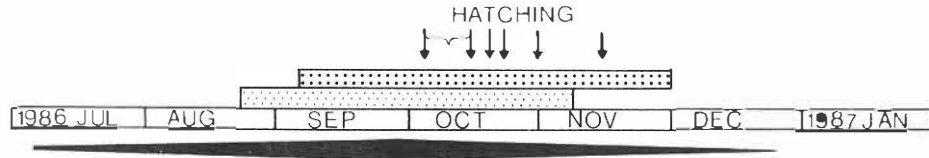


Fig. 4(b)

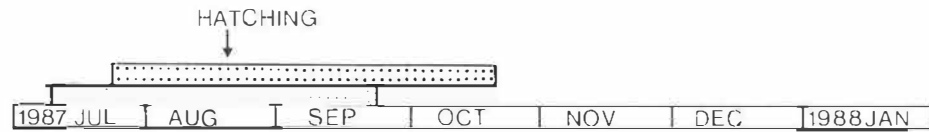


Fig. 4(c)

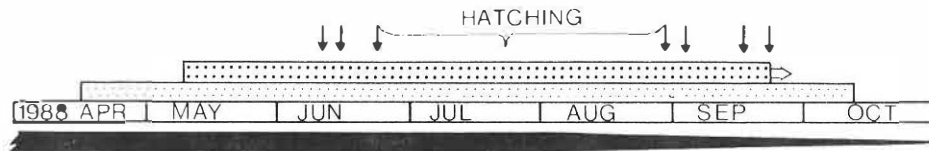


Fig. 4(d)

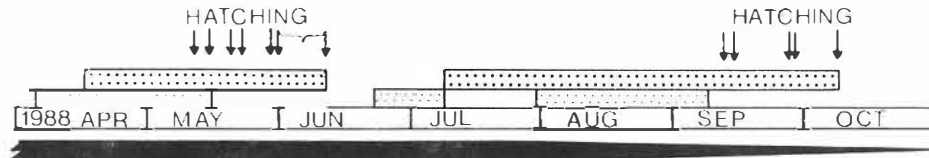


Fig. 4(e)

Figure 4(a). *Maned Duck* laying and incubating periods, and estimated dates of six brood hatchings in relation to wetland inundation in summer 1985/86 (refer 1 under Results). At least 20 *Maned Duck* broods were seen in January 1986.

Figure 4(b). *Maned Duck* laying and incubating periods, and estimated dates of brood hatchings in relation to wetland inundation in spring 1986 (refer 2 under Results). Bracket denotes 14 brood hatchings within this period.

Figure 4(c). *Maned Duck* laying and incubating periods, and estimated date of brood hatching in relation to wetland inundation in spring 1987 (refer 3 under Results).

Figure 4(d). *Maned Duck* laying and incubating periods, and estimated dates of brood hatchings in relation to wetland inundation in 1988 (refer 5 under Results). The bracket denotes a continuous period of brood hatchings. A laying bird was trapped in October, so incubation may have continued beyond the date shown.

Figure 4(e). *Grey Teal* laying and incubating periods, and estimated dates of brood hatchings in relation to wetland inundation in 1988 (refer 5 under Results).

TABLE 3

Waterbird breeding activity in the study area on Nocoleche Nature Reserve during 1988. Times of field trips when observations of breeding activity were possible are shown in Figure 3. Small young,  $\leq$  half adult size; large young,  $>$  half adult size.

Species	Habitat	Breeding times
Hoary-headed Grebe	Deep depressions and tanks	Nest building early April; incubating and small young late May; large young early July.
Australasian Grebe	Tank	Nest building late April; incubating May and July; large young July.
White-faced Heron	Large depressions	Nest building late April; incubating May; large young early July.
Yellow-billed Spoonbill	River	Incubating or nestlings May and early July; large young early July.
Black Swan	Large depressions	Pre-breeding behaviour* early April; laying May; incubating late May; small and large young early July.
Pacific Black Duck	Large depressions	Pre-breeding behaviour* early April; small young early July.
Grey Teal	Depressions and river	Pre-breeding behaviour* and prospecting early April; laying late April; incubating early May and early July; small young May, late September and early October; large young late July, late September and early October.
Australasian Shoveler	Large depressions	Pre-breeding behaviour* May; small young early July; large young late July.
Pink-eared Duck	Large depressions	Prospecting early April; small young late May; large young July.
Maned Duck	Depressions	Prospecting April; laying late April, early May, July, late September, early October; incubating May, July; small young July, late September, early October; large young late July, late September, early October.
Black-tailed Native Hen	Depressions with lignum	Laying or incubating July**.
Brolga	Large depressions	Incubating late May; small young early July; large young early October.
Masked Lapwing	Large depressions	Incubating and small young early July.
Red-kneed Dotterel	Large depressions	Large young late September.
Black-fronted Dotterel	Large depressions and river	Large young late September.
White-winged Stilt	Large depressions	Incubating or nestlings late July.

\*Courtship, pair bond maintenance, sexual displays; \*\*One predated nest found.

mid July. The nest on Momba Swamp produced two young Brolgas, which were beginning to fledge in late July (Table 3).

Rain in June and early July maintained the 'Nocoleche' wetlands at an almost constant level from the end of May until the second half of July 1988, when windy conditions began to reduce water levels and areas. By late September the small depressions were dry or nearly so, and the larger wetlands were shallow and covered about half of their former area. Waterbird habitat in the area was scarce by the second half of October, and by late November 1988 surface water was once again only in the permanent waterholes, ground tanks and the river channel. By December 1988 almost no waterbirds remained in the study area. The total rainfall for 1988 was 338 mm (Fig. 3).

#### *Individually-marked Maned Ducks*

A total of 597 Maned Ducks was colour banded at Nocoleche Nature Reserve during the study. Twenty per cent of these were resighted or recaptured, but half of these resightings or recaptures were within a week of the bird being banded. Only 16 Maned Ducks were recaptured or resighted during subsequent flood events. A male banded at Claypan Tank (Fig. 2b) in October 1986 was recaptured four times during the next 11 months at the same site. A female banded while incubating in September 1987 also at Claypan Tank was recaptured at the same site in May 1988, again incubating. Another female and her nine ducklings, which were about one and a half weeks old, were banded in October 1986 at Ram Tank (Fig. 2b). Six of these ducklings were recaptured a month later, still

flightless, at Peka Tank about 6 km distant (Fig. 2b). The intervening terrain was shrub covered sandplain with depressions about 400 m apart. The same female was seen again in August 1987 at Claypan Tank with four young ducklings (and a different mate). She was recaptured at this same site again in May 1988 and found to be laying. Four days later she was incubating her third clutch in three successive seasons. In 1986 she probably began laying in late August, in 1987 in mid June, and in 1988 in the first half of May.

Eight Maned Ducks banded at Nocoleche Nature Reserve were recovered from elsewhere (>300 km distant), up until April 1990. Five of these were retrieved from New South Wales, between 300 and 500 km from Nocoleche N.R.; and three were retrieved from Victoria, between 750 and 800 km from Nocoleche N.R. The times between initial banding of these Maned Ducks and their retrieval varied from three to 25 months.

## DISCUSSION

In the three and a half years of the study the wetlands in the study area filled and dried three times, including in 1985 and 1986, which were years of below average rainfall at Nocoleche N.R. The formation of waterbird habitat on the Reserve during the study was a fairly frequent, if not a reliable, event.

Forty-nine species of waterbirds used the study area, 18 of which bred there. The study area is only 22 per cent of the 'Nocoleche' wetland system, which in turn is only part of the potential waterbird habitat of north-western New South Wales (Figs. 1, 2a). The more arid but otherwise similar 'Delalah' wetland system in dunefields west of the study area has eight times the wetland area of the 'Nocoleche' system (Goodrick 1984). Although river floods during this study were short-lived, in larger floods the 'Cuttaburra' wetland system, which extends 200 km along the Paroo River and Cuttaburra Creek, also becomes waterbird habitat. Additional wetlands are associated with the Bulloo River (Fig. 1). For a regional perspective on the wetlands in north-western New South Wales and their use by waterbirds, see Maher (1988).

During dry times individuals and small groups of many species were transient in the study area: Pink-headed Ducks, Hardheads, Australasian Shovelers, Australian Pelicans, Black Swans, grebes and many other waterbirds were often seen on permanent water, and sometimes stayed on isolated ground tanks for only a day. Maned Ducks and Grey Teal were usually present on the permanent water, and some Maned Ducks bred on the ground tanks outside flood periods.

Maher (1988) suggested that waterbirds use different wetlands for different stages of their life cycle. The low resighting rate of marked Maned Ducks in this study, and the intermittent presence of all waterbird species, indicate such mobility. The waterbirds may be part of mobile populations for which Nocoleche N.R., or indeed the much wider surrounding area, is one large, constantly changing habitat created by the mosaic of local and regional rainfall (Briggs and Lawler 1991). The band recoveries of Maned Ducks banded at Nocoleche N.R., from elsewhere in south-eastern Australia suggest that the ducks in the study area are part of the greater population of Maned Ducks in south-eastern Australia.

When the dry wetland basins filled, a variety of breeding habitat for waterbirds was created: shallow open water, flooded canegrass, sedge and lignum, small islands, and trees (some with hollows suitable for nesting ducks) fringing or standing in the water. The high value of recently flooded, previously dry, wetland basins for waterbird breeding is discussed by Maher and Carpenter (1984), Briggs and Maher (1985) and Crome (1986, 1988). The flooded depressions on Nocoleche N.R. (the 'Nocoleche' wetland system) provided excellent habitat for Maned Ducks which grazed on plants growing after rain, and used the flooded depressions to raise their broods. Together with their fledglings, they then fed on the banks of the depressions which produced low green herbage as water levels receded. Maned Ducks could feed and breed on such depressions, even when they were not fully inundated. By contrast, Grey Teal and other duck species were more constrained by the depth of water. They only bred when water levels in the depressions were high, and were less able to use the residual stages of the wetlands.

The timing of breeding in Australian ducks has been discussed by Braithwaite (1976), Frith

(1982), Crome (1986) and Fullagar *et al.* (1988). The observations reported here indicate that a small number of Maned Ducks bred regularly on permanent water at Nocoleche N.R. (for example in spring 1987), and a large number of Maned Ducks bred opportunistically when ephemeral wetlands flooded following rain at other times of the year (as in summer 1985/1986, spring 1986, and autumn, winter and spring 1988). Breeding in Grey Teal was more closely tied to substantial wetland fillings. They laid after wetland-filling rain in November 1985; in 1986 they laid only after a heavy downpour greatly increased the area of wetland flooded (even though there had been good but steadier rain before, and Maned Ducks had already started nesting); and they did not breed in the spring of 1987. No broods of Grey Teal were seen before late May. No broods of Maned Duck were seen until early July 1988, when they were all less than 14 days old. Thus, there was no indication of laying in either species before April, even though flooded wetland habitat was available from the beginning of January. However, a previous, similar wetland filling at Nocoleche N. R. in January 1984 led to Grey Teal and Maned Ducks incubating in mid February (M. Maher, pers. comm.). Grey Teal had a second major laying period in August and early September 1988. This may have been the result of some birds laying regularly in spring, or it could have been in response to the major topping up of wetlands in winter of that year.

Few broods of Pacific Black Duck, Pink-eared Duck and Australasian Shoveler were seen. Those that were showed that Black Ducks and Shovelers breed at times of the year other than spring at Nocoleche N.R. (both laid in mid May in 1988), and that Pink-eared Ducks bred in response to wetland availability in a similar way to Grey Teal, without the delay observed in some studies conducted elsewhere (Frith 1982). Black Swans, Hoary-headed and Australasian Grebes, Brolgas, White-faced Herons and Royal Spoonbills were also recorded breeding at Nocoleche N.R. in autumn and winter when suitable habitat was available.

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