Breeding biology of the Black Swan *Cygnus atratus* in southeast Queensland, Australia

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Abstract

The breeding biology of Black Swans *Cygnus atratus* ringed on the Gold Coast of southeast Queensland, Australia, was studied from 2007–2012. Numbers breeding ranged from 13–23 pairs *per annum* and included between 23–39 recorded breeding attempts by marked birds each year (total = 185 attempts over the 6-year study), of which 36% of all breeding attempts were unsuccessful. In years of high rainfall, total numbers of breeding pairs and breeding attempts were higher, as was the percentage of breeding failures. Of 119 instances of pairs recorded breeding, 63% bred once per year, 26% bred twice, 31, 6% three times, 3% four times and 3% bred five times in one year. Over half of all follow-on breeding attempts were preceded by a successful breeding attempt; in four cases, three broods of cygnets were hatched in a single year. On average, birds nesting 3–5 times per year had no better productivity per breeding attempt than those nesting only once or twice, although they did produce more cygnets each year. Birds were first recorded pairing at 2–4 years of age, and first recorded breeding at 2–5 years (most at three years old). The mean number of cygnets hatched per breeding attempt varied between 1.61–2.61 cygnets for each year of the study and the mean number of cygnets reared to fledging varied from 0.96–2.20 cygnets per breeding attempt. Cygnets hatched in every month of the year except for November, with the highest numbers hatched in March–April and August–September. Results from this study of Black Swans breeding territorially are compared with earlier observations of Black Swans nesting colonially in Australia and New Zealand.

Key words: Australia, Black Swan, colonial breeding, territorial breeding, Queensland.

The Black Swan *Cygnus atratus* is endemic to Australia and is widespread along the east coast from Cairns to as far south as Tasmania, and in the southwest part of the country (Marchant & Higgins 1990). The species was introduced to New Zealand in the 1800s (Miers & Williams 1969), where it now occurs across both the north and south islands. Studies of the swans' breeding biology have been undertaken in several

of Australia's states including Tasmania (Guiler 1966), central New South Wales (Braithwaite 1981a,b) and tropical north Queensland (Lavery 1964, 1971), and detailed observations have also been conducted in New Zealand (Miers & Williams 1969; Williams 1981a). The species nests both colonially and territorially (Marchant & Higgins 1990), with the majority of work published to date focusing on swans nesting in breeding colonies (*e.g.* Williams 1981a; Guiler 1966; Braithwaite 1982). Few have considered territorial breeding pairs, however, or compared the success of territorial *versus* colonial nesting strategies. Preliminary analyses by Williams (1981a) indicated that more cygnets are reared successfully by territorial rather than by colonial breeders, but this appears to be one of few comparative studies available.

Information on the timing of Black Swans' breeding season suggests that this may vary across the range. In New South Wales, breeding attempts have been recorded in every month of the year, albeit most frequently between April and August (Frith 1982), whereas there appears to be greater seasonal variation in breeding elsewhere. In Northern Queensland, for instance, there was a marked February–June breeding season, and breeding pairs were found to have only one clutch per year (Lavery 1971). However, Guiler (1966) found that some birds may nest more than once if the first nesting attempts fails, and both single and multiple breeding attempts by pairs in a single calendar year have been documented in southeast Queensland (Coleman 2010). Moreover, Braithwaite (1981a) demonstrated that captive Black Swans have the ability to breed several times during a single breeding season. Circumstances under which single or multiple breeding attempts per year occur, however, have yet to be clarified.

Few data are available on hatching and rearing success for Black Swans in their natural habitats, although Frith (1982) documented an average of 4.1 cygnets hatched per pair (with 2.7 fledged) and Miers and Williams (1969) recorded between 3.2–3.9 cygnets hatched over a 3-year study period (published information is summarised in Table 1). Breeding success has been linked to rainfall, with birds in New South Wales having a breeding success rate of ≤ 47% in drought years compared to 68% in non-drought years (White 1986), and water levels have a significant effect both on breeding success and the extent of the breeding season. (Guiler 1966; Miers & Williams 1969).

This paper presents new information from Black Swans breeding territorially in sub-tropical southeast Queensland. It compares data on the duration of the breeding season, hatching and rearing success, and the number of breeding attempts each year, with previously published data for the species nesting in temperate and tropical regions. Variation between breeding seasons is considered in relation to local weather conditions (*i.e.* whether these are wet or dry years). Additionally, the paper compares breeding success recorded for territorial pairs observed during this study with records for the more widely documented colonial-nesting Black Swans studied in other parts of Australia and New Zealand, to make a preliminary assessment the success of the different breeding strategies. The relative

Table 1. Available data on breeding seasons, hatching success and rearing success from Black Swan studies in Australia and New Zealand.

Study Site	Breeding Season	Breeding Strategy	Mean cygnets hatched	Mean cygnets reared	Percentage cygnets reared from total hatched	Reference
New Zealand (South Island)	July–Oct	Territorial	no data	no data	65%	Williams 1981a
New Zealand (South Island)	Sept–Nov (but variable between years)	Colonial	3.2–3.9	no data	42%	Miers & Williams 1969; Williams 1981a
North Queensland	Feb–June	Territorial	4.4	no data	no data	Lavery 1964, 1971
Western Australia	May–Oct	Territorial	no data	no data	no data	Halse & Jaensch 1989
Tasmania	June–Oct	Colonial	4.8	3.7	77%	Guiler 1966
Central New South Wales	Dec–Feb (but highly variable)	Colonial	4.1	2.7	66%	Frith 1982
Southern Queensland	All year	Territorial	1.0–2.6	1.0–2.2	69%	This study

merits of breeding once *versus* several times in a single year are considered, and the ages at which territorial Black Swans first pair and breed are also described.

Methods

Study area

Black Swans have been studied in southeast Queensland since 2006, in an area ranging from the New South Wales border in the south to Brisbane River in the north (Fig. 1). The study area has a wide range of freshwater and marine sites, with breeding and non-breeding swans occurring throughout the region. Large flocks of up to 900 non-breeding birds can be seen offshore, feeding in the shallow coastal waters of Moreton Bay, with smaller flocks of 10–100 birds frequenting freshwater sites

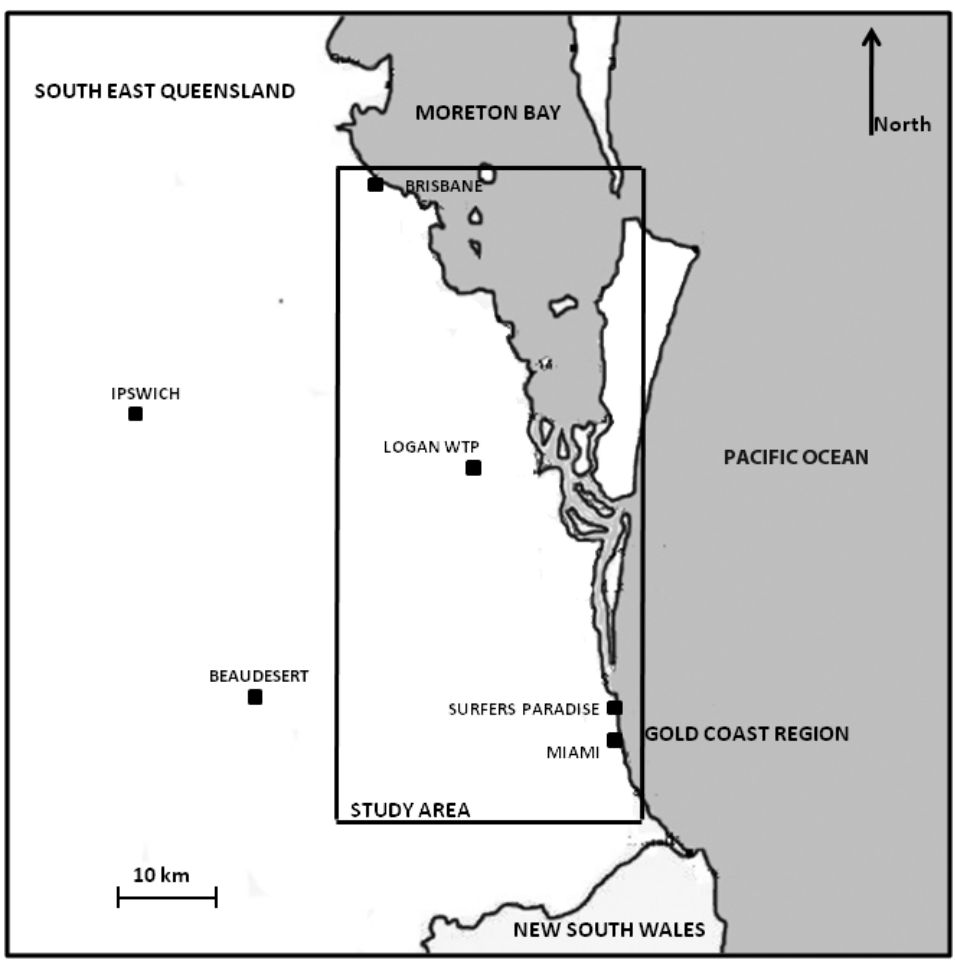

Figure 1. The Black Swan study area in southeast Queensland, Australia.

in the study area. Although some freshwater sites used by non-breeding birds are near the Brisbane area, most are further south, on man-made pools and canals 1–2 km inland from the Surfers Paradise and Miami. Breeding birds are found throughout the study area but the highest numbers are found on the Gold Coast. Almost all nests occur on man-made water bodies, on pools or larger lakes surrounded by houses or on golf courses. In addition to their natural food, the majority of Black Swans take food provided by humans, and supplementary feeding of bread and grain is now commonplace.

Climate in the study area is subtropical, with warm humid summers and cooler drier winters. Monthly rainfall and temperature data and annual rainfall totals recorded at the Logan Water Treatment Plant weather station (–27.71°S, 153.23°E; station no. 040854), which is mid-point in the study area, were downloaded from the Bureau of Meteorology website (www.bom.gov.au) for analysing the effects of weather conditions on the Black Swans' breeding season.

Catching and ringing

Birds were caught by hand throughout the year, using bread or grain to attract them close enough to be captured. Each bird caught was then aged from its plumage characteristics, sexed cloacally, and fitted with two rings: a standard Australian Bird and Bat Banding Society metal leg-ring and a red plastic leg-ring engraved with a unique white alphanumeric code readable in the field. The swans were also measured (skull and tarsal lengths) and weighed to the nearest 0.1 kg. The parentage of birds ringed as cygnets was recorded whenever possible, in order to determine the fate of offspring for known individuals.

Monitoring techniques

One to two days each month, a fixed route was travelled through the study area, visiting all sites where Black Swans were known to occur. Surveys were made in the mornings, between 06:00–12:00 h Australian Eastern Standard Time (AEST), during which the numbers of birds at each site were counted and their status recorded: as non-breeding, paired, breeding or cygnet. A juvenile bird still associating with its parents was classed as a cygnet, and a paired bird that had attempted to nest during that year was classed as a breeding bird. Breeding attempt was defined as the pair building a nest and incubating eggs. Swans obviously associating and exhibiting territorial behaviour were considered to be paired; any birds, alone or in small groups and flocks, were considered to be non-breeders.

Each month the swans' ring numbers were read using binoculars (in some cases using bread and grain to attract birds closer), to build-up life history data for known individuals. Attempts were also made to catch and ring as many unringed birds as possible during the monthly surveys. Associations data were recorded for marked individuals (especially whether they were with a ringed or an unringed mate), to determine the age of first pairing and breeding, mate fidelity and the number of cygnets hatched and reared to fledging for each breeding attempt. For paired birds, the month of breeding was also noted, to describe the timing of the breeding season

Results

A total of 341 swans were caught and ringed in the study area between 2007–2012, of which 42 were first ringed as paired birds and 36 caught as cygnets or non-breeders and subsequently paired or bred at least once during the study. A further 103 birds ringed as cygnets and 196 birds ringed as non-breeding flock birds were not seen with mates or young.

Age of first pairing and breeding

Of 15 males of known age subsequently recorded as paired, five (33.3%), eight (53.3%) and two (13.3%) were first seen to be paired at 2, 3 and 4 years old, respectively. Likewise, for 11 known age females, five (45.5%), four (36.4%) and two (18.2%) were first recorded as paired at 2, 3 and 4 years old.

Eleven males were of known age when seen breeding for the first time, of which two (18.2%), seven (63.6%), one (9.1%) and one (9.1%) first bred in their 2nd to 5th year of life. Females showed a similar pattern, with eight known age birds first seen breeding at age 2 years (2 individuals), 3 years (4 individuals) and 4 years (2 individuals). No birds were recorded either pairing or breeding for the first time at ≥ 5 years old, though this may reflect the relatively short study period (6 years to date) for a long-lived species. Despite males apparently pairing and breeding slightly later than females, there was no significant difference between the sexes in the age of first pairing or first breeding (Mann-Whitney U tests: U = 76.5, n = 15, 11, P = 0.66 and U = 43, n = 11, 8, P = 0.92).

Of the 139 birds banded as cygnets or first year birds, 67 were males and 72 were females of which a further 6 males (8.9%) and 11 females (15.2%) were subsequently recorded, either as paired or breeding, in subsequent years. However, it could not be confirmed that other birds in this group had not at some point paired or bred and remained undetected, as in almost all cases swans remained undetected for several months at a time at some point in the study.

Breeding season

Between 2007–2012, 118 successful breeding attempts were recorded, with the month of hatching recorded reliably for 93 of those attempts. Birds hatched cygnets in every month of the year except for November (Table 2), but hatching incidence did vary significantly across months (χ^2_{11} = 22.91, P < 0.02). Peaks in hatching activity were recorded in January, March–April and August–September with fewer clutches hatched in February, May, October and December. The months in which cygnets hatched also appeared to vary between years. January was the only month in which broods hatched in every year of the study, and cygnets also hatched in March, April, July and September in 5 of the 6 years (Table 2).

Table 2 also suggests annual variation in the duration of the breeding season, with cygnets hatching in 9 months of the year in 2010 and 2012, compared to only 5 months in 2011. Nevertheless, this apparent difference in the number of months in which cygnets hatched did not vary significantly between years (χ^2_5 = 4.68, P > 0.05).

Table 2. Number of Black Swan pairs that hatched cygnets each month in southeast Queensland, for each year of the study.

Month/Year	2007	2008	2009	2010	2011	2012	Years breeding recorded
Jan	3	1	4	1	1	1	**6**
Feb			1	1		1	**3**
Mar	1		6	1	2	1	**5**
Apr	2	5		2	1	3	**5**
May		1		1		1	**3**
Jun	1	3	3	2			**4**
Jul		1	1	3	3	2	**5**
Aug	2	6		3		4	**4**
Sep	3		4	1	4	1	**5**
Oct	1	2					**2**
Nov							**0**
Dec	1					1	**2**
Months in which breeding was recorded	**8**	**7**	**6**	**9**	**5**	**9**	

Number of breeding attempts

A total of 185 breeding attempts were recorded over the duration of the study (Fig. 2). There was a significant positive correlation between total annual rainfall and the number of breeding pairs and the number of breeding attempts in each year, with the largest number of breeding pairs and breeding attempts in the years with highest rainfall (Spearman Rank correlation: $r_{11} = 0.81$, $P = 0.05$ and $r_{11} = 0.81$, $P = 0.05$ respectively). Of 119 pairs identified and recorded breeding, 75 (63.0%) nested only once in any calendar year, and a further 31(26.1%) bred twice in some years. There were seven examples where breeding pairs bred three times (5.9%), three pairs bred four times (2.5%) and three pairs bred five times (2.5%) during the year (Fig. 3). Forty (63.5%) of the 63 follow-on breeding attempts recorded followed successful breeding, where cygnets were seen to have hatched. The remaining 36.5% of follow-on breeding attempts following a failed breeding attempt.

Of the 44 cases where pairs nested more than once per year, 19 (43.2%) resulted in a

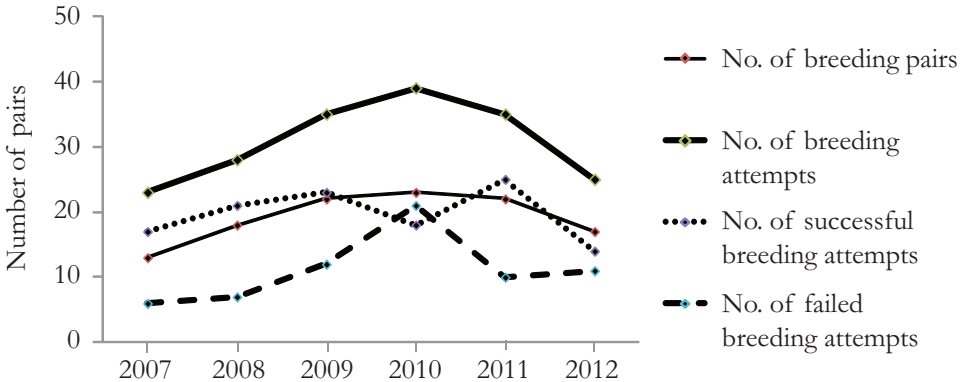

Figure 2. Number of breeding pairs and breeding attempts per year for Black Swan pairs monitored in southeast Queensland between 2007 and 2012.

second brood being hatched in that year and four (9.1%) resulted in three broods being hatched in a single year. Six (13.6%) of those pairs nesting more than once in a year (including one case of five breeding attempts in a single year) resulted in no cygnets being hatched; the remainder produced just one brood, despite multiple breeding attempts.

Productivity

The number of breeding pairs ranged from 13–23 and the number of breeding attempts from 23–39 each year (Fig. 2). Of the 185 breeding attempts recorded from 119 annual breeding events by pairs, 118 of those breeding attempts resulted in a total of 364 cygnets hatched and 254 reared. In only 25 (21.2%) of the 118 cases where cygnets hatched did the young fail to survive to fledging.

Of all breeding attempts recorded, 36.2% failed to produce cygnets, and this varied between years with only 25.0% of breeding attempts failing to hatch cygnets in 2008 compared to 53.9% in 2010, which was also the wettest year of the study (Fig. 2).

The mean number of cygnets hatched per breeding attempt varied between 1.61 and 2.61 over the years, and the mean numbers reared ranged from 0.96–2.20 cygnets. There was no significant difference in the average number of cygnets hatched or reared per breeding attempt between years ($\chi^2_5 = 0.3$ and $\chi^2_5 = 0.7$ respectively, $P > 0.05$ in each case), despite there apparently being fewer cygnets per breeding attempt in years of higher rainfall.

The average number of cygnets hatched and reared per breeding attempt did not differ significantly between birds that nested once as opposed to those that nested several times per year (ANOVA: $F_{4,177} = 0.92$, $P > 0.05$ and $F_{4,114} = 0.99$, $P > 0.05$, respectively). However, birds nesting more than once per year hatched and reared significantly more cygnets in a year than their counterparts which made fewer nesting attempts (Fig. 4, ANOVA: $F_{4,113} = 9.65$, $P < 0.01$ and $F_{4,114} = 5.34$, $P < 0.01$,

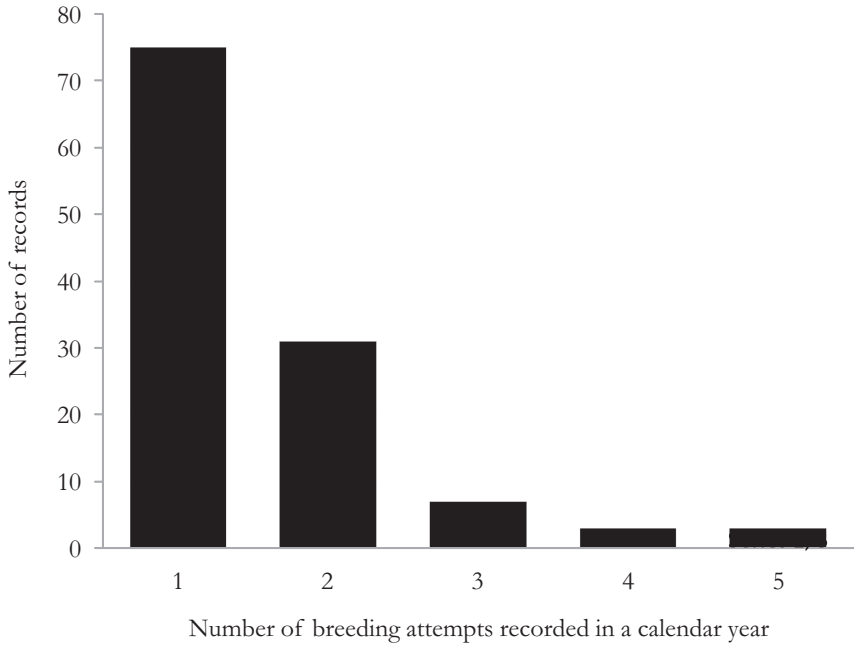

Figure 3. Number of breeding attempts recorded per year by Black Swan pairs in southeast Queensland between 2007 and 2012.

respectively), with means of 2.19 and 1.57 cygnets hatched and reared per annum for pairs breeding once per year compared to means of 6.50 and 4.00 cygnets hatched and reared per annum for those nesting 4–5 times per annum.

Discussion

Data collected on Black Swans breeding territorially in sub-tropical Queensland indicated that the species has a very broad breeding season, with cygnets hatched in almost every month of the year. This contrasts observations of more seasonal breeding amongst territorial pairs in more tropical (Lavery 1971) and temperate study areas (Guiler 1966; Miers & Williams 1969; Table 1).

Although most pairs (63%) observed in Queensland bred only once per annum, the remainder bred up to five times each year. Such levels of breeding activity have not been documented for Black Swans in studies elsewhere, although multiple breeding is known for birds in captivity (Braithwaite 1981a). Over half of the subsequent within-year breeding attempts followed successful breeding in which cygnets hatched, resulting in pairs sometimes defending two, or even three generations of cygnets simultaneously.

Age of first pairing and breeding

Only 8.9% of males and 15.2% of birds banded as cygnets or one-year-old birds were recorded as either pairing or breeding. However, in almost all cases the other

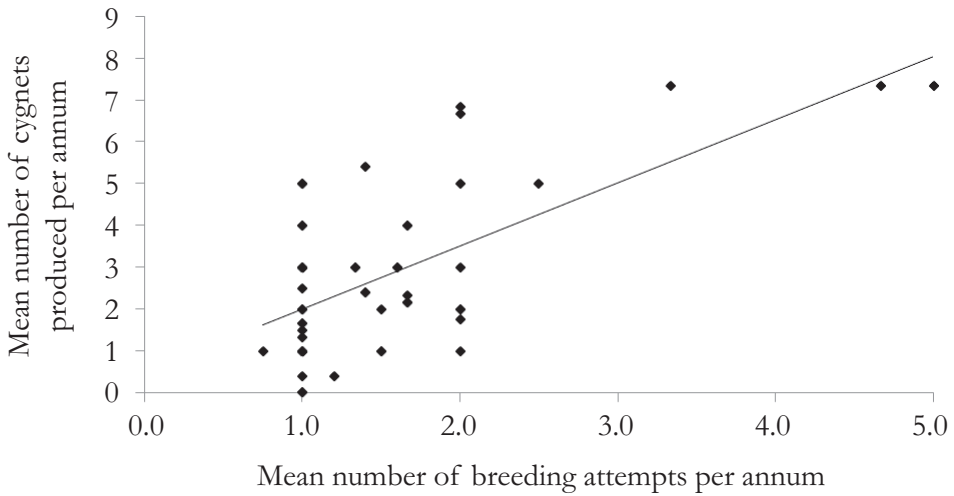

Figure 4. The effect of number of breeding attempts on the number of cygnets produced by breeding Black Swans in southeast Queensland between 2007 and 2012.

birds in this cohort were not recorded continuously throughout the study, and therefore others could have paired or bred and remained undetected. The median age of first pairing and first breeding was 3 years for both males and females monitored during the 6-year study. Anecdotal evidence from New Zealand (Williams 1981b) suggests that juvenile birds return to their breeding sites in their fourth year, suggesting that they commenced breeding at that time, and the age of first pairing and breeding is also similar to other swan species with most not breeding till more than 2 years old (Scott 1972; Rees *et al.* 1996). This is despite the fact that in at least some swan species, including the Black Swan (Braithwaite & Frith 1969; Braithwaite 1981a) and Mute Swan (Dawson & Coleman 1991), individuals are capable of breeding at an earlier age. The reasons for a delayed onset of breeding is likely to be behavioural, with juvenile birds in other swan species relying on non-breeding flocks to learn required behaviours in relation to social interactions and pairing (Minton 1971), and time constraints on the annual migratory and breeding cycle may result in deferred onset of breeding for migratory species (Rees *et al.* 1996). Non-breeding Black Swans are routinely territorial towards each other in flocks (Tingay 1974), so it is likely that the majority of subadult Black Swans lack the social- and dominance-related attributes required to pair, hold a territory and breed successfully in their first years of life.

Breeding season

There was little evidence for seasonality in breeding, with pairs hatching cygnets in almost all months of the year, contrasting with other published studies. While Black

Swan nests have been recorded all year round in New South Wales, much of this variation was between years and linked to rainfall, with breeding occurring after heavy rainfall periods and a marked breeding season within years (Frith 1982). Elsewhere the breeding season is less variable with breeding in June–August in Western Australia (Halse & Jaensch 1989), February–May in Northern Queensland (Lavery 1967) and August to October in the south island of New Zealand (Miers & Williams 1969; Table 1). In New Zealand the timing of breeding was also related to water levels and the season varied slightly between years in relation to availability of breeding habitat. However, once breeding began it was highly synchronised (Williams 1981a). Williams also showed that territorial breeders on sites with stable water levels had a much more predictable breeding season.

The lack of clear breeding seasonality in south-east Queensland is therefore unusual and difficult to explain. Southeast Queensland does not experience extremes of seasonal temperature variation or extended periods of tropical rainfall, despite having warm wet summers and drier colder winters, so climate is unlikely to inhibit year-round breeding. Additionally, almost all the breeding sites monitored in this study are man-made and the land around them actively managed as parks and gardens or for sport such as golf courses. The management practises on these sites may artificially increase the nutrient load in these territories, encouraging extended plant growth. Additionally, supplementary feeding by humans is also common (J. Coleman, pers. obs.). Both of these factors may also help in extending the breeding season.

Number of breeding attempts

Although > 60% of pairs in this study bred only once in a calendar year, the remainder bred two or more times and follow-on breeding attempts followed successful cygnet hatchings in almost half of recorded cases. While Braithwaite (1981b) demonstrated that, in captive birds, females had the ability to lay up to eight clutches in a year and rear three broods in a 12 month period, none of the published studies to date on Black Swans in their natural habitats have highlighted repeat breeding on this scale, although re-nesting following failed breeding attempts has been noted (Miers & Williams 1969; Guiler 1966). Several studies (*e.g.* Frith 1969; Guiler 1966) have however demonstrated opportunistic breeding in this species, with re-nesting and breeding delayed or commencing earlier, in response to local conditions. Data from this study suggest that, at least in some territories, conditions are suitable enough to allow birds to breed repeatedly throughout the year and the lack of seasonal extremes may remove the environmental constraints on breeding seasonality.

The energetics of breeding multiple times in a year require far more investigation, but was not attempted here because it was impossible to compare body condition of birds that nested once per year with those nesting multiple times, or to compare the relative habitat qualities of the territories involved. To lay an average clutch of 5 eggs (Miers & Williams 1969) at a rate of one egg every 1–3 days (Braithwaite 1977) and then

incubate those eggs to hatching for an average period of 41 days (Braithwaite 1977) would mean that a female laying five clutches and hatching three broods in a year would spend at least 200 days per annum engaged in nesting activities, a significant investment.

Year round supplementary feeding by the public could have a significant influence on the condition of breeding birds, allowing them to breed multiple times in a year by removing some natural constraints such as food availability. The Black Swan is also one of the few Anatidae in which males assist with incubation (Braithwaite 1977) and Brugger & Taborsky (1994) hypothesised that this behaviour may have evolved to support opportunistic breeding allowing birds to breed quickly, when conditions are suitable and potentially more than once, by reducing the reproductive costs of incubation on females. In this study it is highly likely that this, combined with the favourable climate and abundant year-round food, all contribute to the multiple breeding attempts that some pairs undertake.

Productivity

Hatching rates (1.6–2.6 cygnets) and rearing rates (1.0–2.3 cygnets) in this study appear to be lower than Black Swan breeding success data from New South Wales (4.2 and 2.7 respectively; Frith 1982), and also for colonial nesters over a three year period (3.2 and 3.9; Miers & Williams 1969). The majority of territories in the study area were impoundments used for stormwater drainage, with summer storms or years of high rainfall causing water levels at these sites to fluctuate as a result of runoff (J. Coleman, pers. obs.), which in turn resulted in nests and clutches being lost to flooding (J. Coleman, pers. obs). Similar observations were made by Tingay *et al.* (1977) where agricultural runoff into lakes and dams results in nesting failures. Such artificial conditions may therefore provide apparently good habitats for feeding but be poor habitats for breeding as a result.

The number of follow-on breeding attempts in relation to productivity has not been documented before. Whether this is a response to the apparently low productivity in the study area, or simply a function of year-round suitable breeding conditions is not possible to answer with the available data. However it is clear from the results in this study that the number of cygnets both hatched and reared each year is significantly increased for birds breeding multiple times *per annum*.

Despite apparently poor productivity, 69.8% of the cygnets hatched in south-east Queensland were reared to fledging which compared well with 65% amongst territorial families but only 52.2% amongst crèches from colonial pairs in New Zealand (Williams 1981a). Williams (1981a) noted that colonial breeding was opportunistic and associated large flocks of birds in the breeding season potentially limiting territorial breeding opportunities. Nowhere in the Queensland study were there large flocks of non-breeders utilising suitable breeding habitats and each year, there appear to be a number of apparently suitable territories vacant suggesting that availability of breeding sites is not a constraint on territorial breeding in this study.

The results from southeast Queensland raise a number of questions about the Black Swan's breeding biology, and further work is needed to explore these. Data on the ages of breeding birds and annual body condition should be compared between single and multiple breeders. Comparing the frequency of supplementary feeding at sites with differing breeding strategies, as well as sampling of natural food resources in different territories, would also help to establish whether reproductive output is related to natural or human-supplemented food supply. Comparing breeding season extent and numbers of breeding attempts between the suburban and rural birds breeding on farm dams and lakes in southeast Queensland would further help towards explaining factors affecting these breeding strategies.

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Photograph: Nesting Black Swan at Pacific Pines, Gold Coast City, Queensland, Australia, by Jon Coleman.