THE BIOLOGY OF THE SHORT-BILLED FORM OF THE WHITE-TAILED BLACK COCKATOO, CALYPTORHYNCHUS FUNEREUS LATIROSTRIS CARNABY

by

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Summary

The biology of the White-tailed Black Cockatoo was studied within three main terms of reference:-

1. Taxonomy, zoogeography and speciation.
2. Breeding biology, food, movements and population dynamics.
3. Behaviour.

1. The two forms of the White-tailed Black Cockatoo (*Calyptorhynchus baudinii*) and their relationship to the Yellow-tailed Black Cockatoo (*C. funereus*) are reviewed. The differences between the long-billed (*C. baudinii*) and short-billed (*C. latirostris*) forms of the White-tailed Black Cockatoo are presented: the long-billed form has a longer wing, differently shaped maxilla, different cranial morphology, different food preferences and different contact calls; the breeding and foraging ranges of the two forms are presented and discussed. Based on these differences, the two forms are treated as separate species. The results of an examination of museum material and literature on the Yellow-tailed Black Cockatoo are presented. On this evidence the Yellow-tailed Black Cockatoo is divided into three subspecies, *C. funereus funereus* (eastern Victoria and north to Berserker Range, near Rockhampton, Qld), *C. f. xanthanotus* (southern Victoria, south-eastern South Australia to lower Eyre Peninsula, Kangaroo Island, Tasmania and King, Flinders and Cape Barren Islands, Bass Strait), and *C. f. latirostris*, which is white-tailed and here transferred from *C. baudinii* (south-western Western Australia in the drier inland sandplain and mallee areas).

The similarities between *C. f. xanthanotus* and *latirostris* are stressed. It is suggested that a continuous population of a stock jointly ancestral to *funereus* and *baudinii* across southern Australia was split climatically and *C. baudinii* arose from the western isolate and developed specialised adaptations for feeding on the fruits of Marri, *Eucalyptus calophylla*. A subsequent invasion later gave rise to *C. f. latirostris* which was reproductively isolated from *C. baudinii* by different habitat and calls.

2. The breeding biology of *C. f. latirostris* was studied at two main study areas: Coomallo Creek, an area with large tracts of uncleared land; and Manmanning, an area of extensive clearing with little native vegetation remaining.

Cockatoos nested in any species of eucalypt that had a hollow of suitable size. Eggs were laid between July and November with birds at Manmanning starting about four weeks after those at Coomallo Creek. Clutch size was a maximum of two; incubation took 28-29 days and usually both eggs hatched. The second nestling usually died within 48 hours of hatching.

Rates of growth for weight and length of folded left wing were calculated for nestlings from both areas. These rates of growth were compared within areas between years and between areas within years. There was little difference in rates of growth of nestlings between years at Coomallo Creek but at Manmanning there were significant differences.

In both areas the birds were found to rely on native vegetation, particularly the seeds of the Proteaceae for food. Coomallo Creek with its large tracts of uncleared vegetation appeared to have an

adequate food supply whereas Manmanning with little remaining vegetation did not.

During the non-breeding season birds from Coomallo Creek were found to wander locally within 50 kilometres of the breeding area while birds from Manmanning undergo a definite migration to the coast.

This study depended on the use of individually marked birds carrying wing-tags. Calculations based on tag sightings revealed that the birds had an annual loss of 30-40% giving a further life expectancy of about 2.5 years. This was incompatible with their period of immaturity (4 years) and their low reproduction rate. It appeared that differential predation may have been acting on the population with the tagged birds suffering a higher predation rate due to the conspicuous markings on the wings (tags).

3. The study of behaviour is based on populations in the field augmented by studies made in the aviary.

A catalogue of the behaviour of birds is given and consists of both movements, postures and vocalisations. It was found that the birds were able to identify an individual from its call.

Sequential analyses were carried out on the behaviour of males from field and aviary populations. Males in aviaries were found to perform more agonistic, comfort and maintenance displays than males in the field and this appeared to be a result of their confinement in aviaries.

A description of the behaviour of birds in the field throughout the year is also given.

1. General introduction and aims.

The black cockatoos of the genus Calyptorhynchus are found only in Australia and Tasmania. Four species are at present recognised within the genus: the Red-tailed Black Cockatoo (*C. magnificus*), the most widely distributed of them all, occurring over much of mainland Australia; the Glossy Black Cockatoo (*C. lathami*) of Kangaroo Island, coastal New South Wales and Queensland; the Yellow-tailed Black Cockatoo (*C. funereus*) of Kangaroo Island, south-eastern South Australia, coastal Victoria, New South Wales and Queensland, and on Tasmania and the Bass Strait islands; and the White-tailed Black Cockatoo (*C. baudinii*) with a very limited range in the south-west of Western Australia.

The White-tailed Black Cockatoo, despite its limited range has been regarded as a pest by the Forests Department as a result of the birds' attacks on seed cones in *Pinus* plantations. Their activities also cause broken or chewed growing points resulting in deformed trees. They also attack orchards, damaging apples and pears to dig out the seeds. Initially, a study was commenced into the pest status of the bird and this revealed that there were two forms of the White-tailed Black Cockatoo and these results have been published (Saunders 1974b and 1974c). As there was very little published information about the biology of ~~the~~ these conspicuous birds or of any of the cockatoos, this study was conducted concentrating on the short-billed form of the White-tailed Black Cockatoo which was responsible for the damage to pine plantations.

The aims of this research were: to revise the classification of the short-billed form of the White-tailed Black Cockatoo and examine its relationship to the Yellow-tailed Black Cockatoo; to study the breeding biology, food, movements and population dynamics of the bird; and to describe and discuss the behavioural activities of an unrestricted colony of the birds in their natural conditions augmenting this with studies conducted in aviaries to clarify certain problems raised by studies made in the field. The information gained from this research was to be used in the formulating of guidelines for the management (for control or conservation purposes) of this species.

2. Study areas

2.1 Introduction. The locations of the study areas are shown in Figure 1 and were at Coomallo Creek, Manmanning, Tarwonga and Moornaming. These four areas were selected because they are widely spaced over the birds' distribution. Coomallo Creek and Tarwonga each represent a central point in the birds' northern and southern distribution while Manmanning and Moornaming represent points on the eastern edge of the birds' distribution to the north and south. The difference in day length were minimal but there were differences in climate and habitat. Each study area is described separately and summarised in Table 1.

2.2 Coomallo Creek. This area lies on the line of the Dandaragan Scarp, approximately 220 km north of Perth. It is only since the second world war that advances in farming have made it possible to utilise this country (Beard, 1976) and most of the agricultural clearing in this area has been done over the last fifteen years.

2.2.1 Climate. Climatic figures are shown in Table 2 and the rainfall figures have come from Badgingarra, 24 km south and the temperature figures from Eneabba, 40 km north. The monthly rainfall figures for the years of the study for Coomallo Creek itself are given in Figure 2.

2.2.2 Size. The study area, of 6,750 ha, has large tracts of uncleared land within it (Figure 3). The nesting area is a large belt of woodland which sweeps up through the middle of the study area and most of this has been left uncleared. Scattered within it and around it are patches of sandplain heath. The locations of the available nest sites are shown in Figure 3.

TABLE 1

The four study areas

	Coomallo	Manmanning	Tarwonga	Moornaming
Years of operation	1970-1976	1970-1976	1970	1970
Latitude	30°11'S	30°51'S	33°05'S	33°34'S
Longitude	115°28'E	117°06'E	117°06'E	118°04'E
Altitude (m)	300	335	290	310
Vegetation	Woodland/ sandplain heath	Mainly cleared/ scattered woodland	Woodland	Mainly cleared/ scattered woodland
Annual Av. Rainfall (mm)*	564	389	505	433
Two wettest months	June & July	June & July	June & July	June & July
% of total rainfall occurring during June and July	46%	39%	37%	36%
% of total rainfall occurring in 6 months October-March	15%	22%	22%	27%

* At nearest meteorological station (Badgingarra, Wongan Hills, Narrogin and Nyabing).

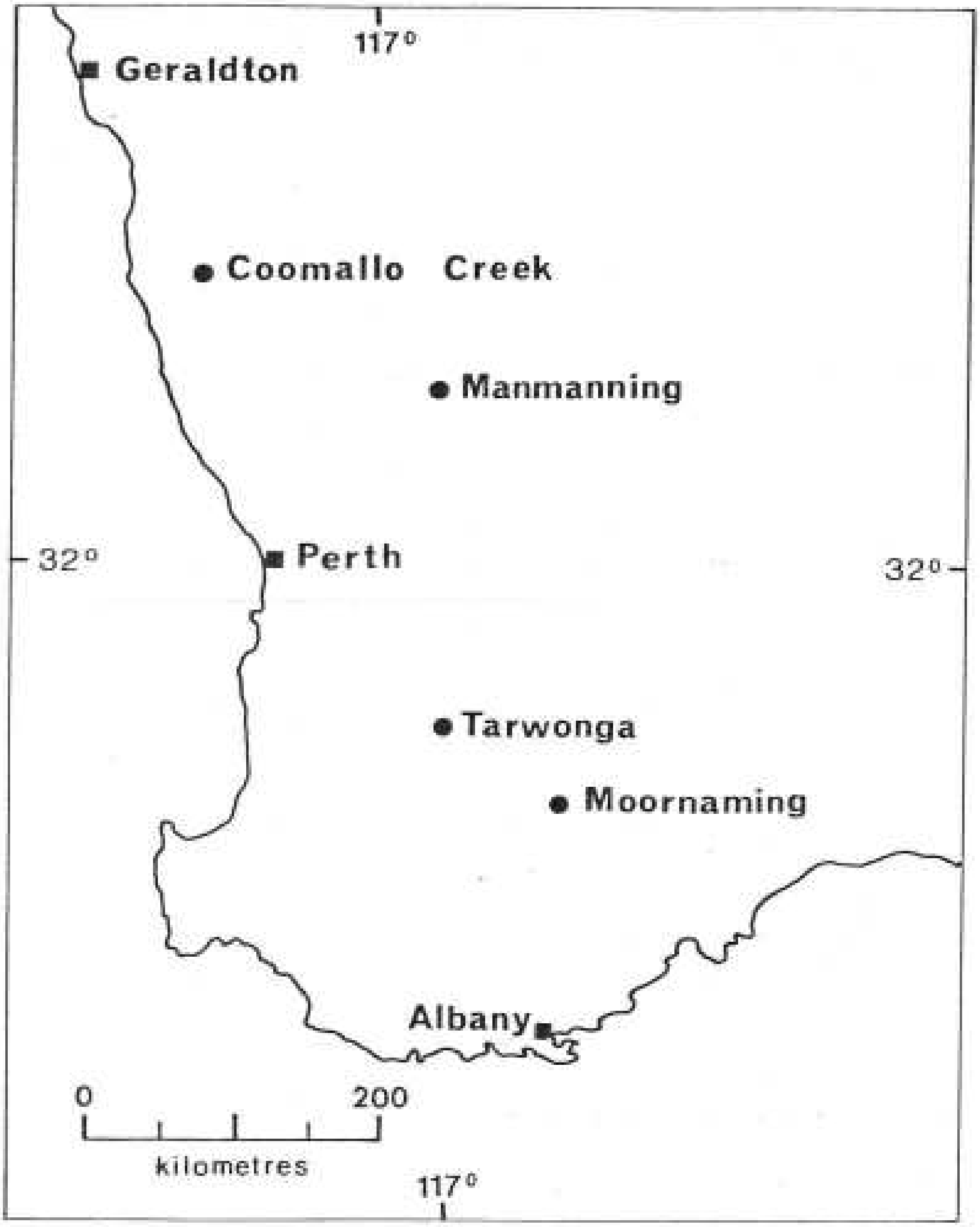


Figure 1. Locations of the study areas.

2.2.3 *Topography.* The area is hilly with flat-topped hills and gullied escarpments and is the upper catchment for the Coomallo Creek.

2.2.4 *Vegetation.* The woodland area is predominantly Wandoo (*Eucalyptus wandoo*) with small patches of York Gum (*E. loscophleba*) and Acacias. The sandplain heath is characterised by low dense scrub dominated by the Myrtaceae, Leguminaceae and the Proteaceae which are particularly well represented by a number of species of *Banksia*, *Dryandra*, *Hakea* and *Grevillea*. The strips of land along the roads (verges) in this area are all at least 200 m wide and have not been cleared of vegetation.

2.3 *Manmanning.* This area is in the wheatbelt and has been settled since the late 1920's. It has been extensively cleared for agriculture.

2.3.1 *Climate.* The climatic figures, taken from Wongan Hills, 35 km west, are given in Table 2.

The monthly rainfall figures for Manmanning itself during the period of the study are given in Figure 2.

2.3.2 *Size.* The birds forage over an area of 48,400 ha around the nesting area. The location of this nesting area within the main study area is shown in Figure 4. A 458 ha reserve in the centre of the study area is uncleared and the rest of the area is cleared farmland with small patches of uncleared land around homesteads, along some of the roads and along the railway line. There are also some isolated trees standing in paddocks.

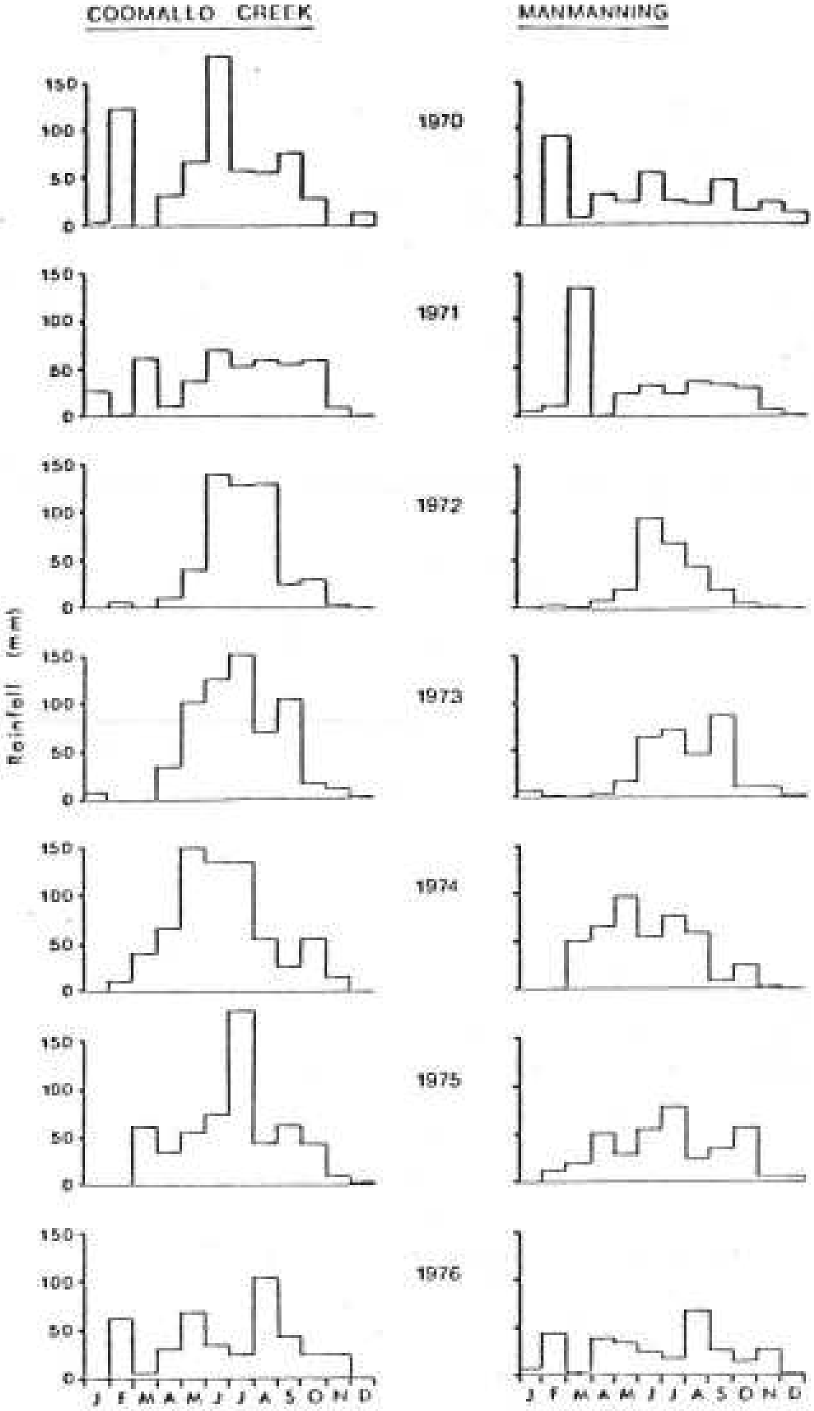


Figure 2. Monthly rainfall histograms for Coomallo Creek and Manmanning (1970-1976).

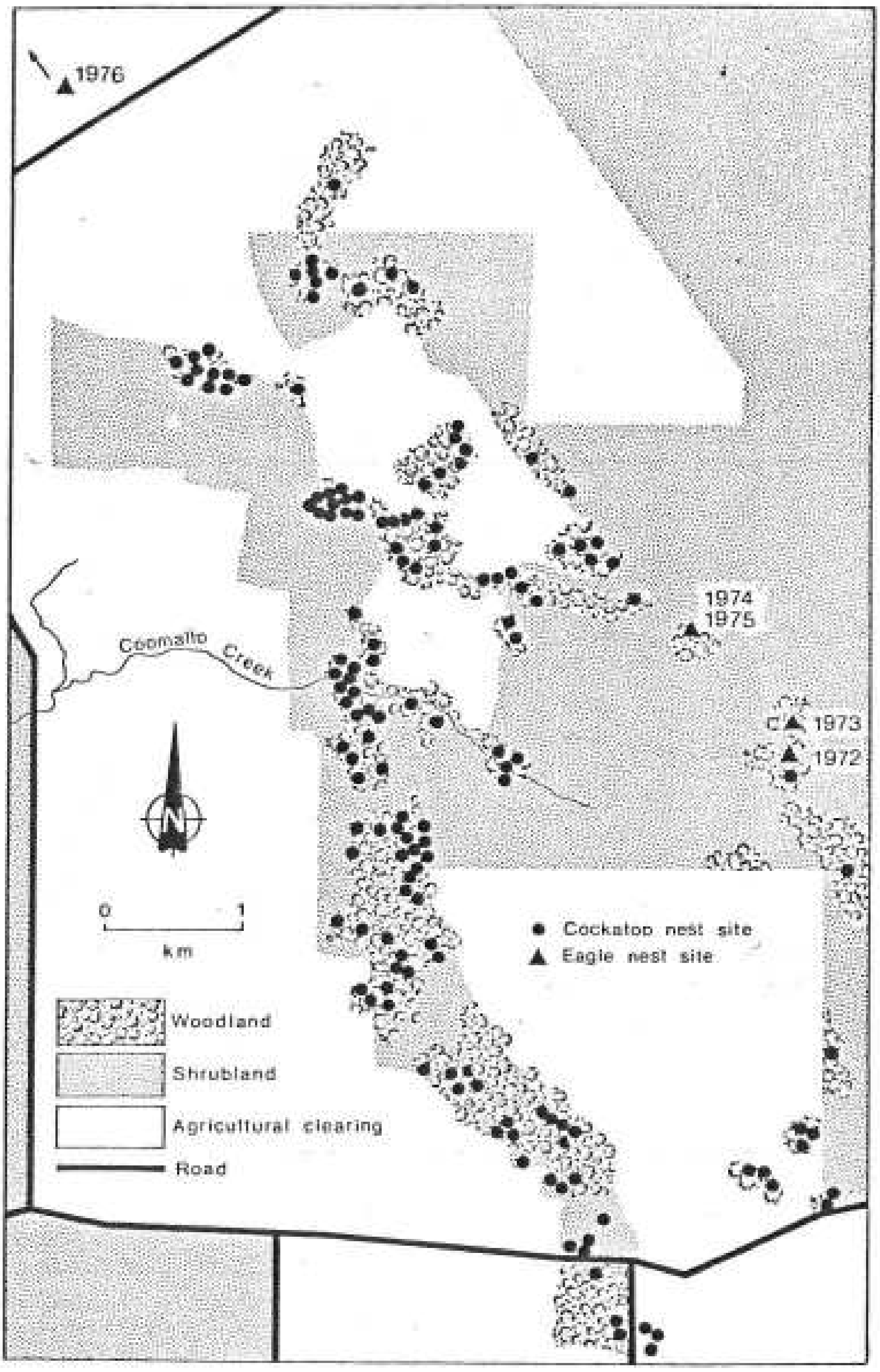


Figure 3. Coomallo Creek study area showing locations of nest sites.

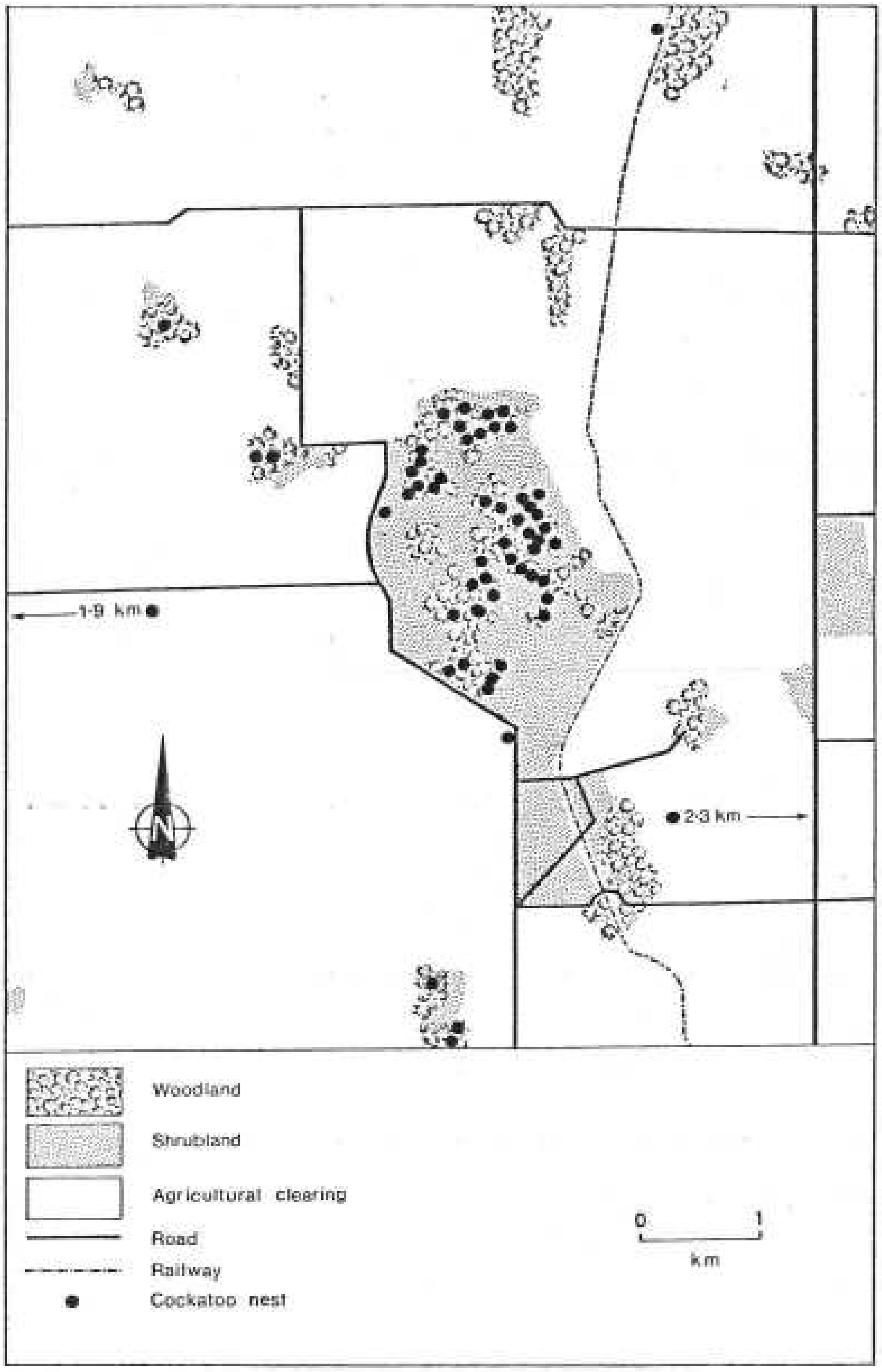


Figure 4. Manmanning study area showing locations of nest sites.

TABLE 2

Climatic data for the four study areas

(Data from Bureau of Meteorology)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
ENEABBA (COOMALLO CREEK)													
Av. Daily Max. Temp. (°C)	34.6	35.7	32.2	26.8	22.9	19.5	19.1	19.1	21.4	26.1	29.0	33.1	26.6
Av. Daily Min. Temp. (°C)	16.5	18.2	15.7	12.7	9.5	9.0	7.1	6.8	7.5	10.1	11.6	15.0	11.6
Av. Rainfall (mm)*	16.8	15.5	10.4	32.0	79.5	140.0	119.1	80.8	27.7	32.5	7.1	2.8	564.2
WONGAN HILLS (MANMANNING)													
Av. Daily Max. Temp. (°C)	34.1	33.1	30.7	25.4	19.7	16.7	15.8	16.7	19.8	22.9	27.5	31.0	24.5
Av. Daily Min. Temp. (°C)	17.9	17.6	16.2	12.7	9.4	7.2	6.1	6.0	7.3	9.2	12.0	14.9	11.4
Av. Rainfall (mm)	10.9	12.5	21.8	22.4	52.3	80.0	70.9	51.6	27.2	19.6	9.9	9.9	389.0
NARROGIN (TARWONGA)													
Av. Daily Max. Temp. (°C)	30.9	30.0	26.7	22.2	18.1	15.0	14.5	14.6	16.7	20.9	25.1	29.2	22.0
Av. Daily Min. Temp. (°C)	14.7	14.5	12.8	10.4	7.4	6.8	5.3	5.0	5.8	8.0	10.4	12.5	9.5
Av. Rainfall (mm)	9.9	16.5	21.8	29.7	65.3	93.0	91.4	68.8	48.0	33.5	15.5	11.7	505.1
KATANNING (MOORNAMING)													
Av. Daily Max. Temp. (°C)	30.3	24.9	26.7	22.7	18.2	15.4	14.3	15.4	17.7	20.6	25.2	28.4	22.0
Av. Daily Min. Temp. (°C)	13.4	13.5	12.4	10.2	7.8	6.6	5.3	5.5	6.3	7.6	9.9	12.1	9.2
Av. Rainfall (mm)†	12.5	17.8	20.6	26.2	52.3	94.5	63.0	49.0	37.1	30.2	18.5	11.7	433.4

* From meteorological station at Badgingarra

† From meteorological station at Nyabing

Figure 5. Road verge at Manmanning showing paucity of native vegetation

2.3.3 *Topography*. The area is a flat plain with small isolated hillocks.

2.3.4 *Vegetation*. The remnant woodland is dominated by Salmon Gum (*E. salmonophloia*) with some Gimlet (*E. salubris*) and Wandoo occurring in it. On the sandplain heath there are Mallees in isolated shrubs or in thickets and on the poorer soils there are *Acacia* thickets. *Casuarina*, *Hakea*, *Grevillea*, *Banksia* and *Dryandra* are all well represented in the remnant sandplain heath.

The roadside verges are only 10-15 m wide (Figure 5) whereas the railway line verge is about 60-80 m wide, and in both cases, most of the original vegetation has been removed.

2.4 *Tarwonga*. This area, also within the wheatbelt, has been settled since late last century and consists of cleared farmland, privately owned uncleared areas and State Forest. Like Moornaming it was only used as a study area during 1970 (see section 3.8).

2.4.1 *Climate*. Climatic figures are taken from Narrogin, 19 km north, and are given in Table 2. The monthly rainfall figures for Narrogin in 1970 are given in Figure 6.

2.4.2 *Size*. The study area was 8,170 ha and contained three forestry reserves used in the study which were 504 ha, 99 ha and 729 ha. Well over one third of the study area was uncleared land.

2.4.3 *Topography*. The area was flat with some rolling hills.

2.4.4 *Vegetation*. The woodland areas are Marri (*E. calophylla*) with Wandoo occurring in the valleys or on areas of alluvial white

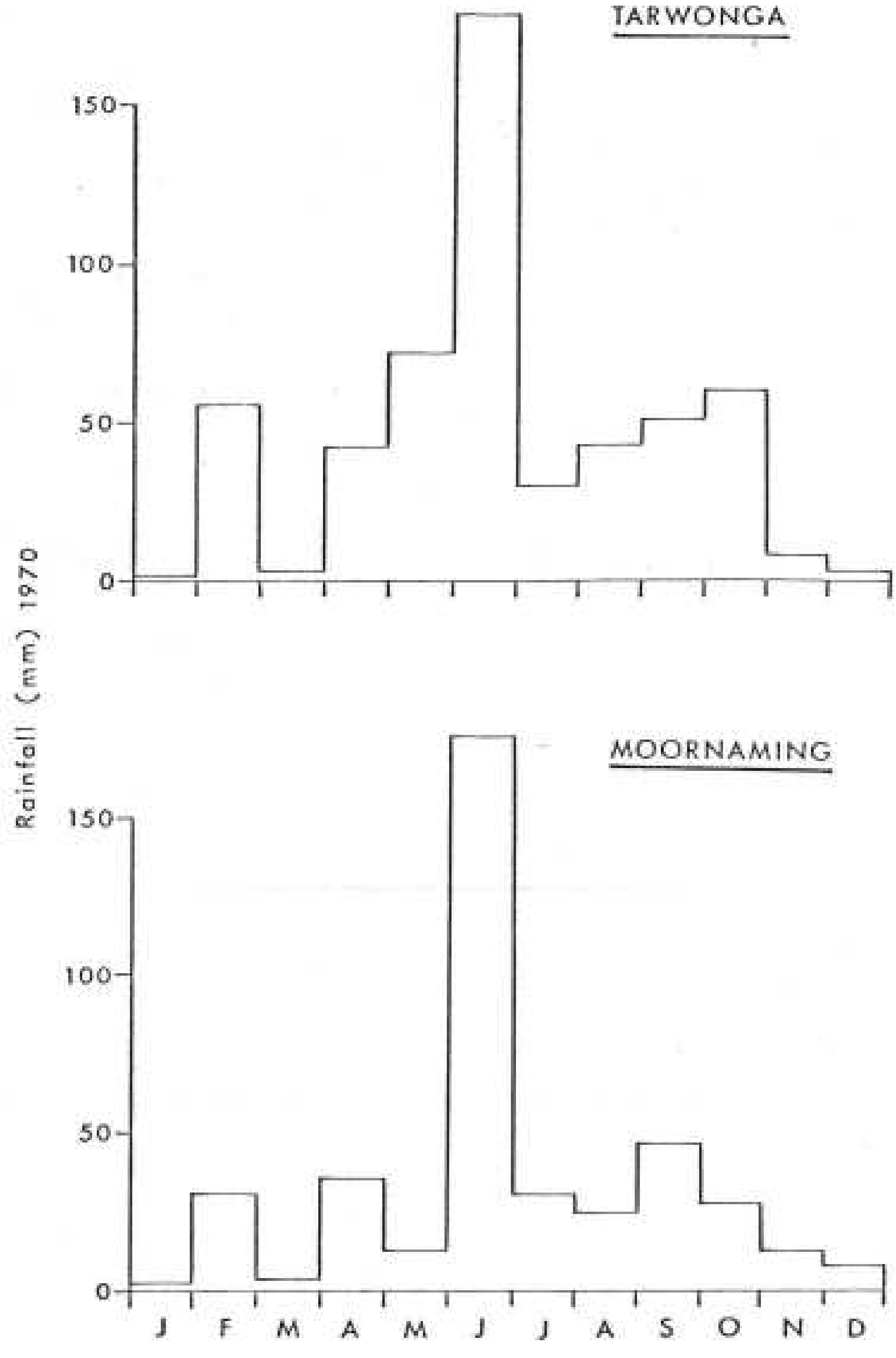


Figure 6. Monthly rainfall histograms for Tarwonga and Moornaming (1970).

sand. Brown Mallet (E. astringens) is found around the breakaways. The shrub layers are dominated by myrtaceous and proteaceous species. The roadside verges are only 10-15 m wide but much of the original vegetation remains.

2.5 Moornaming. This area, also in the wheatbelt, has been settled since the turn of the century and has been extensively cleared.

2.5.1 Climate. The climatic figures are given in Table 2. The temperature figures are from Katanning, 51 km west and the rainfall figures from Nyabing, 14 km east.

The monthly rainfall figures for Moornaming for 1970 are given in Figure 6.

2.5.2 Size. The study area was an uncleared reserve set aside for a town and another reserve for water catchment. These two reserves, totalling 177 ha, are woodland with some sandplain heath surrounded by cleared farmland. There is more uncleared land in this region than there is around Manmanning.

2.5.3 Topography. The area is a flat plain.

2.5.4 Vegetation. The woodland is dominated by Salmon Gum with Swamp Yate (E. occidentalis) in the wetter alluvial flats. Sandplain heath occurs on the edge of the woodland areas and Casuarina, Hakea, Grevillea and Dryandra are well represented. The roadside verges are only 10-15 m wide with most of the original vegetation remaining.

3. Methods.

3.1 Trapping. In the four breeding study areas adult birds were trapped in their nest hollows. Breeding female cockatoos could not be trapped until their nestling was at least three weeks old. Experience showed that if females are handled while they are on eggs or a very young nestling, they are liable to desert. (Of 9 females trapped on eggs, 7 deserted). Once the nestling is about three weeks old the females no longer brood all the time and spend some of the day out feeding. This allows a trap to be positioned on the hollow while they are absent. Females brood their nestlings all night so it is possible to return quietly to the nest area after dark and close the trap thereby catching the female.

Suitable wing tags were not developed in time for use during the breeding season of 1970 and so only bands (or leg rings) were used in that year. After 1971 the females were banded, tagged and then replaced in the hollow. Just after dawn the following morning they were released. The males usually stayed in the nest area until after their females were released and the pair flew off together.

Breeding males were more wary than females and some of them never entered the hollow if a trap was on it. This accounted for the higher proportion of females in the sample. After the males had been caught, banded and tagged, they were released and usually flew away at once. I know of no cases of desertion attributable to handling of the males. In one case when a male was banded and tagged at mid-morning, then released, it was back feeding the nestling that same evening.

No other trapping method was used in these four study areas. At Gnangara pine plantation, on Perth's northern outskirts, and Red Gully, 100 km north of Perth, cannon nets were used during the non-breeding season in partly successful attempts to trap members of the large groups of cockatoos frequenting these areas. If many birds were caught under the net at one time each tended to bite another bird near it and caused considerable physical damage. In view of this type of damage, firings were made only when small numbers of birds were under the nets. Altogether 43 birds were caught and tagged in six firings for a total of 43 separate attempts. The birds seemed to avoid nets set in the same spot for at least a week after a successful firing.

3.2 Banding. Black cockatoos have a very short tarsus and a very powerful bill. In 1970 the Australian Bird Banding Scheme obtained stainless steel leg bands which were suitable for use on cockatoos. Every bird handled received a leg band (size 21) on its left leg, and by June, 1977, a total of 804 birds had been banded (Table 3).

Nestlings were banded and tagged in their nest hollows about 2-3 weeks prior to their fledging.

3.3 Tagging. Wing tags were used to identify individual birds and they were attached with a loop of stainless steel wire going through the patagium, coming back under the wing and joined to the wire coming over the wing. The wire was twisted together in such a way that the bird could preen the wire to lie along the line of the

TABLE 3

Number of birds tagged or banded in all areas to June 1977

	Females	Males	Immatures	Total
Coomallo Creek	189	66	347	602
Manmanning	33	25	45	103
Tarwonga	3	3	22	28
Moornaming	3	3	14	20
Red Gully	4	11	18	33
Gnangara	1	2	7	10
Three Springs	2	-	4	6
Piawaning	-	-	2	2
TOTAL	235	110	459	804

secondary flight feathers.

Each bird handled from the beginning of the breeding season in 1971 received one of these wing tags with its own two-letter combination on each wing. The tags were of 0.8 mm stainless steel measuring 41 mm x 29 mm. The letters were 15 mm high and there was about 17 mm separating the centres of the letters (Figure 7). These letters were engraved into the surface of the tag, the engraving being 1.5 mm wide. Three coats of hard red enamel paint were painted into the engraving. These tags have been on some birds for six breeding seasons and they are still clearly readable (as at June, 1977).

A second series of tags was brought into use when the earlier series was finished. They were the same size as the others but coated with an orange plastic compound which was baked on it in a furnace. The engraving was then done on the tags and the letters were the natural silver of stainless steel.

It was found that people returning tags were sometimes unaware that the birds were banded as well. So from 1973 on, all tags had a stick-on label placed on the back, sealed with a clear enamel lacquer and inscribed;

INFORM CSIRO

HELENA VALLEY

W.A. 6056 PHONE

REV. CHG. 946356

The numbers of birds banded or tagged in the different areas are shown in Table 3.

3.4 Handling birds. All birds were removed from the nest hollow using a noose made of PVC electrical conduit with a loop made out of plastic coated curtain wire. This loop was placed over the bird's head and loosely pulled around the neck. No injuries resulted to any adult or immature birds as a result of this type of handling.

Immature birds were lowered back in a bag and deposited on the hollow floor. Adults were placed directly back in the hollow without using a bag.

3.5 Adult measurements. When the adults were trapped, the following measurements and observations were taken from them (Figure 8):-

(1) Maxilla colour.
(2) Culmen length (A).
(3) Maxilla width at widest point.
(4) Rosette colour.
(5) Cheek patch colour.
(6) Left tarsus length (B).
(7) Length of centre claw on left leg (C).
(8) Length of folded left wing (D).
(9) Length of tail.
(10) Weight.

At the end of 1971, this practice was discontinued as additional figures for C. f. latirostris were available from shot specimens collected from a study into the pest status of the White-tailed Black Cockatoo (Saunders 1974c).

Figure 7. Wing tags used on the White-tailed Black Cockatoo

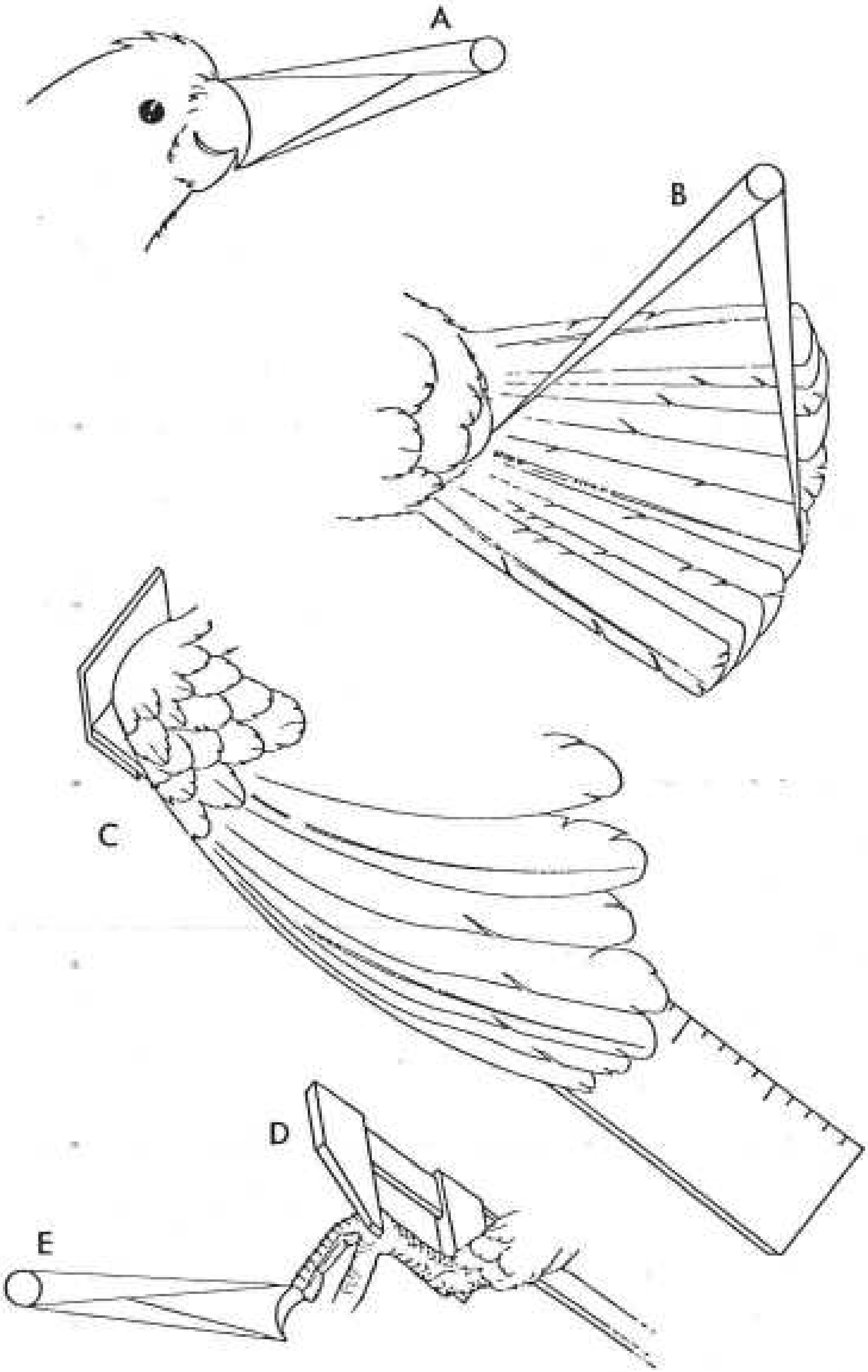


Figure 8. Measurement of cockatoos:-

A. Length of culmen;
B. Length of tail;
C. Length of folded left wing;
D. Length of left tarsus;
E. Length of claw.

3.6 Nestling measurements. Initially every nestling was measured on each visit to the study area from the time the nestlings were at least two weeks old until they fledged. The measurements and observations were taken in the same manner as those from adults.

From the breeding season of 1972 until the end of the breeding season in 1974 only the colouration, the lengths of the folded left wing and tail and the weight were taken on each visit.

In the breeding season of 1975 and 1976 these measurements were made only once on each nestling in order to age it, thereafter it was only handled when it was banded and tagged.

3.7 Egg measurements. Egg measurements were made throughout where it was possible to reach the eggs by hand.

3.8 Nesting studies. In 1970 at the beginning of the breeding season, a subjective search was made in each of the four study areas in order to mark and plot the locations of trees containing hollows apparently suitable for use by White-tailed Black Cockatoos. The following information was recorded from such hollows:

(1) Tree species.
(2) Height of entrance above ground.
(3) Diameter of entrance.
(4) Depth of floor of hollow.
(5) Lining on floor.
(6) Aspect of entrance (i.e. direction hollow opened out to).

Each hollow was marked with a small numbered disc and a record was kept of each visit and what species, if any, was using the hollow.

Any scratching or fresh chipping on the entrance or down the inside of the hollow was noted.

After the 1970 breeding season the study areas at Tarwonga and Moornaming were no longer used because human predation of nestlings affected the results.

At Coomallo Creek and Manmanning, weekly visits were made throughout the 1971-76 breeding seasons. A search was made during the egg-laying period each season to find nests.

The trees were climbed with the aid of a 7.9 m aluminium extension ladder that weighed approximately 34 kg. This ladder could be handled with relative ease by one man, provided there was little or no wind blowing. When anything stronger than a light wind was blowing it became necessary to use two men to erect the ladder. A roof platform on the landrover added an extra 2.4 m to the length of the ladder (Figure 9). Any hollows higher than this combined height could usually be reached with the aid of spikes screwed into the tree beyond the top of the ladder.

3.9 Food studies. The number of breeding birds was small and no shot specimens were collected for crop samples throughout the breeding season. Feeding studies relied on observation of birds whenever they were seen feeding and opportunistic collection of food items (e.g. when an adult regurgitated food when being handled for tagging).

3.10 Observations. Whenever birds were seen they were watched and tags were read with 8 x 56 binoculars where possible or a 40 x 60

Figure 9. Extension ladder set on Landrover for extra height

Figure 10. Hide tower at Coomallo Creek

spotting telescope mounted on a tripod.

To study nesting behaviour a hide was set up so as to watch several nests - never less than three (Figure 10).

During hide watches, voiced notes were recorded and transcribed later. Filming was done with a 16 mm Bolex cine camera at 24 frames/sec. A total of 330 m of cine film was made for later analysis of displays associated with breeding.

3.11 Movements. Band returns from various areas throughout the study gave some idea of the seasonal movements of the birds. Based on this information, searches were made at intervals throughout the non-breeding season. The areas searched included places most likely to be frequented by White-tailed Black Cockatoos, such as pine plantations or other places where food is concentrated, and watering points. All groups seen in these areas were searched for tagged birds. In addition, estimates were made of group size and composition.

3.12 Recording of vocalisations. Vocalisations were recorded using a Sennheiser 804 directional microphone and recorded on a National RQ 421S cassette tape recorder which had an adequate frequency response for recording White-tailed Black Cockatoo calls. The different vocalisations were examined on a sonograph (Kay Electric Co.) later.

An annotation was given to those vocalisations that could be readily recognised and these were recorded when behavioural observations were made.

Individual differences in the main vocalisations were examined from captive White-tailed Black Cockatoos held at Helena Valley.

3.13 Captive birds. Five adult male and nine adult female captive White-tailed Black Cockatoos, all collected from the wild by the end of 1971, were held at Helena Valley and used in a series of behavioural experiments. By the end of the study, one pair had bred successfully and fledged a young (Saunders 1976b).

4. Taxonomy of the White-tailed and Yellow-tailed Black Cockatoo

4.1 Introduction. In the past there has been a great deal of confusion in the literature regarding the classification of the Yellow and White-tailed Black Cockatoos. In view of this confusion a taxonomic review was undertaken.

4.2 Historical introduction. The Yellow-tailed Black Cockatoo was described by Shaw in 1794 and the White-tailed Black Cockatoo by Lear in 1832. Nothing was added to the literature of *C. funereus* Shaw until 1865 when Gould described two different forms of this cockatoo and treated them as separate species. One, which he called the Funereal Cockatoo, *C. funereus*, occurred in New South Wales, or that portion of the Australian continent forming its south-eastern division. The other, the Yellow-eared Black Cockatoo, *C. xanthanotus* Gould, was distributed through Tasmania, on Flinders Island and around Port Lincoln in South Australia. This was said to be smaller than the Funereal Cockatoo. In the same publication Gould regarded *C. baudinii* Lear as a separate species. North (1911) also treated *C. baudinii* as a separate species but stated that because of the shortage of Tasmanian material (3 skins) he could not tell if *xanthanotus* was distinct from the continental form *funereus*. Mathews (1912) recorded the two as subspecies and in 1913 Mathews separated the White-tailed Black Cockatoo into two subspecies: one with a long narrow bill and the other with a shorter wider bill. He later (1917) changed his mind and stated "the very restricted range of this bird is conducive to no subspecific forms". Carnaby (1933) considered that the White-tailed Black Cockatoo in the Lake Grace district of Western Australia was a good subspecies of *C. baudinii* and later he formally named it *C. b. latirostris* Carnaby 1948. Serventy and Whittell (1967) accepted the two subspecies although their nomenclature was incorrect.

Lear's (1932) figure of *baudinii* was of a long-billed bird. Mathews (1913) incorrectly assumed Lear's type was a short-billed bird and then described *tenuirostris* stating that it differed by having a much longer and narrower bill. This specimen is No. 619324 of the American Museum of Natural History and it has a culmen length of 56 mm. *Calyptorhynchus baudinii tenuirostris* is obviously a synonym of *baudinii*. The type for the short-billed form *latirostris* is an adult male No. A6463 at the Western Australian Museum (Carnaby 1948) and it has a culmen of 44 mm.

By the 1960's it was conventional to regard *C. funereus* in eastern Australia and *C. baudinii* in the south-west as two separate species, each with two subspecies. Condon (1975) maintained this arrangement although his nomenclature for the White-tailed Black Cockatoo is incorrect. Forshaw (1969, 1973), however, treated *funereus* and *baudinii* as conspecific under *C. funereus*. Although he acknowledged the possibility that there may be two forms of *baudinii* he made no mention of this possibility in *funereus*.

In 1974 the investigations into the status of the two forms revealed that the long-billed form had a slightly longer wing (Table 8) and a much longer culmen than the short-billed form. The adult skull of the long-billed form was wider, higher, had a longer culmen, lower mandible and gonys than the skull of the short-billed form. In addition there were differences in food preferences between the two forms. On this basis the two forms were kept as subspecies: the long-billed form being _C. b. baudinii_ Lear and the short-billed form _C. b. latirostris_ Carnaby (Saunders 1974c).

In the above study the statistical methods used for analysing the morphological data were univariate analyses of single characters. These data were subsequently re-analysed using multi-variate techniques to study the nature of the morphological divergence between the two forms (Campbell and Saunders 1976). The results of this approach showed that in external and cranial morphology there was a complete separation of the two forms. This was greater than might be expected between subspecies and suggested that the two may be full biological species. Since these reports were published, additional information has been collected on the status of the two forms from which it is concluded that they should be treated as separate species.

Until now, no serious attempt has been made to determine their relationship to the Yellow-tailed Black Cockatoo. In order to do this, museum material in all Australian governmental museums was examined. The first part of this chapter presents the evidence on which the two White-tailed Black Cockatoos have been separated; the second part presents the results of the examination of museum material of the Yellow-tailed Black Cockatoo; and the final part deals with the relationship between the White-tailed and Yellow-tailed Black Cockatoos.

4.3 White-tailed Black Cockatoo

4.3.1 Differences in morphology. The morphological differences between the two forms, baudinii and latirostris, have been well-documented. Saunders (1974c) gave figures and tables showing these differences in both adults and immature birds. The most striking difference between them was the difference in lengths of culmens: adults of baudinii have a mean length of culmen of 53.0 mm (standard error 0.3; range 48-57) (75 individuals) and adults of latirostris a mean of 44.2 mm (SE 0.3; range 34-49) (186 individuals), (see Figure 12). There was no significant difference in the widths of maxillae: adults of baudinii possess a mean width of 21.8 mm (SE 0.2; range 20-24) and adults of latirostris 22.3 mm (SE 0.1; range 20-25).

Two measurements of the exposed maxilla have been taken to emphasise the difference in the shape between the two forms. The manner in which these measurements were made is shown on Figure 11. The measurements were: length of the exposed culmen, and length of the inner tip (showing the more elongated tip of baudinii).

Data included in the results of measurements of the length of the culmen consist of those used in Saunders (1974c), together with additional measurements of adults of baudinii obtained since then. The data on the length of the inner tip of the maxilla has been obtained since the previously published results.

The distribution of length of culmen in 75 adults of baudinii (51 males and 24 females) and 186 adults of latirostris (90 males and 96 females) is shown on Figure 12. The distribution of length

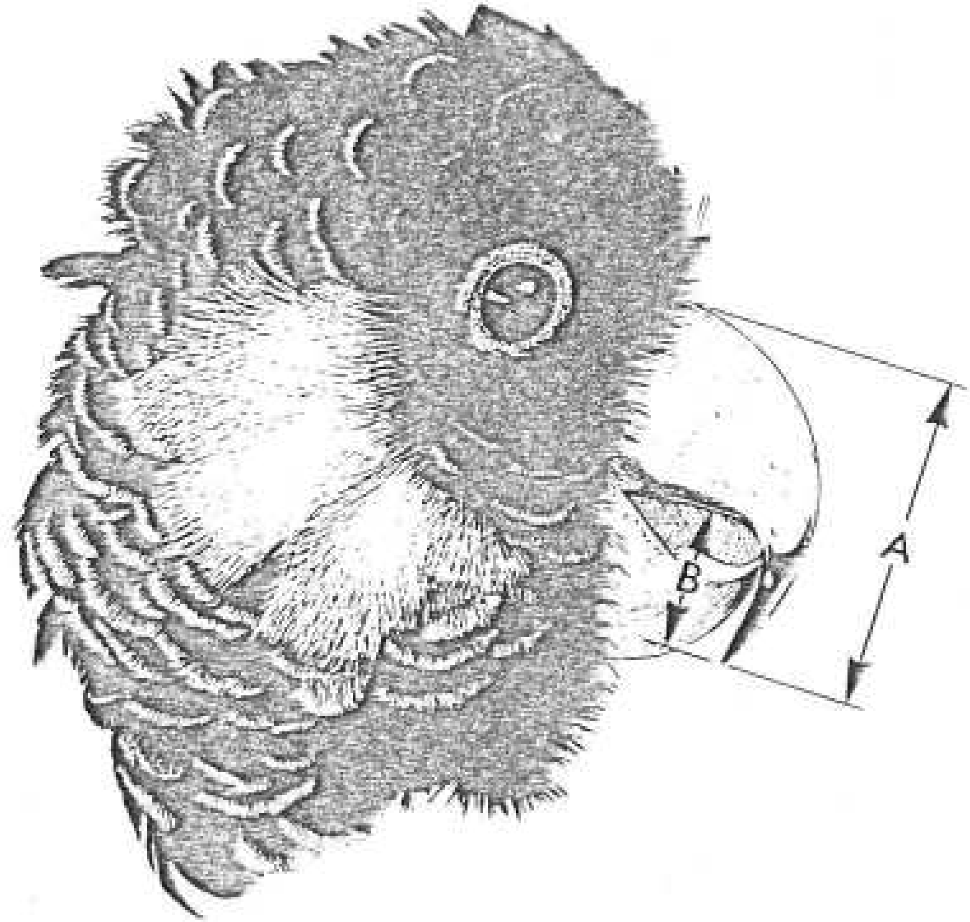


Figure 11. Head of a female of C. baudinii showing two of the measurements of the maxilla discussed in this thesis:-

A. Length of exposed culmen
B. Length of inner tip of maxilla.

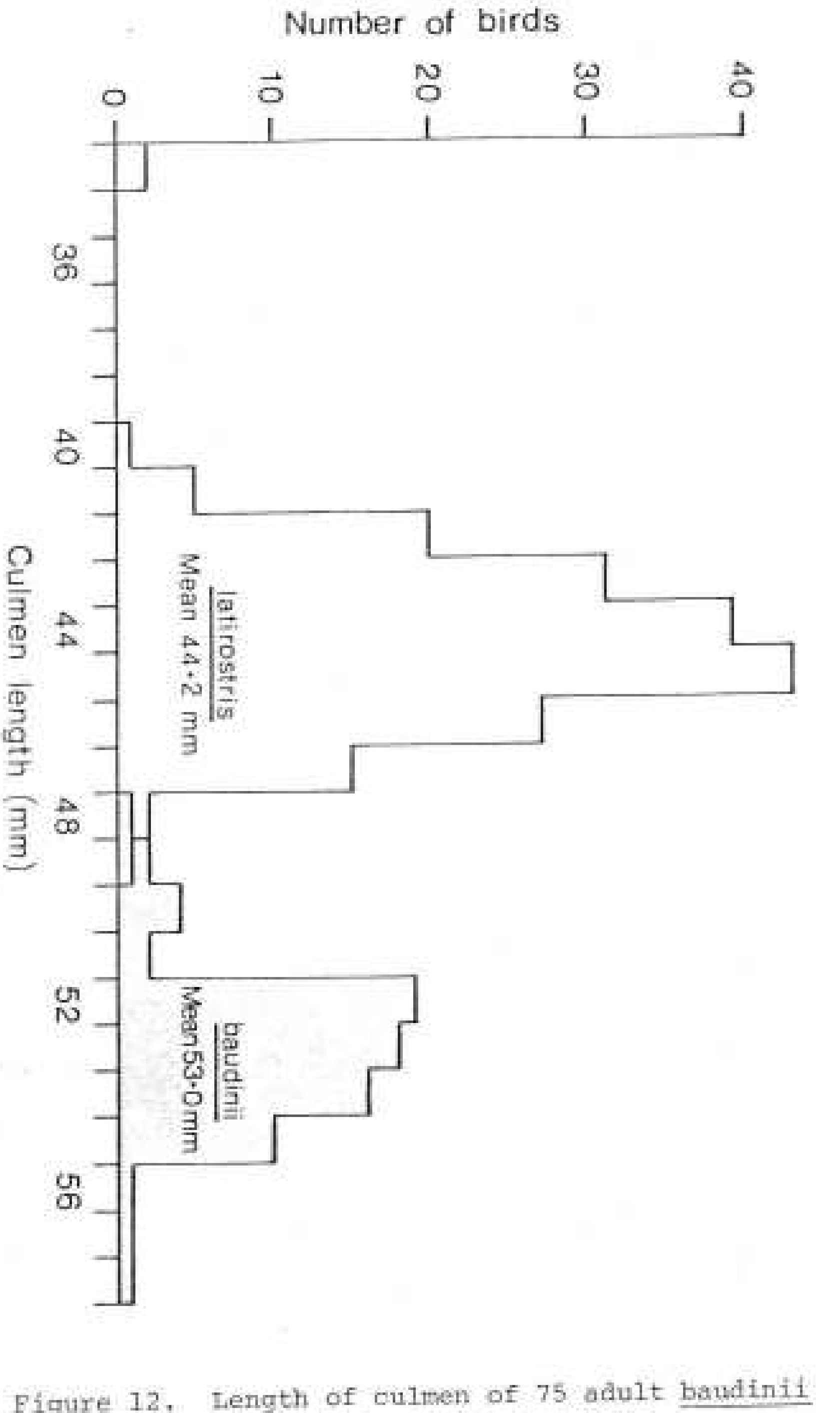


Figure 12. Length of culmen of 75 adult *baudinii* and 186 adult *latirostris* specimens.

of culmen of 36 immatures of baudinii (21 males and 15 females) and 107 immatures of latirostris (44 males and 63 females) is shown on Figure 13.

In adult birds there was little overlap in length of culmen (Figure 12) between the ranges of adults of baudinii and latirostris (3 out of 75 baudinii [4%] was the extent of the overlap). The distribution within each sample showed the pattern of normal distribution with no departures from this at the point where the two distributions overlap. There was more overlap in the ranges in the samples of immature birds (Figure 13). Three out of the 36 (or 8 per cent) immatures of baudinii fall within the range of latirostris.

It has been found from measurements on growth rates of nestlings of latirostris, that latirostris fledges with a culmen of 39.0 mm or greater in length (35 specimens). Despite these measurements, two adults (both males) and one immature female had culmens of only 34 mm. All three were individuals that were close to or larger than average in other dimensions, and had probably sustained damage to the culmen which resulted in the shorter overall length. Three immature individuals with lengths of culmens of 37 or 38 mm were all females and all were smaller than normal (480, 500, 570 grams as compared with a mean of 612 and a range of 480-750).

From nestlings of latirostris which fledge with a culmen of 39 mm or greater in length, which is 88 per cent of the mean length of culmen of adults, then nestlings of baudinii might be expected to fledge with a culmen of 46 mm (i.e. 53 x .88) or greater in length. This

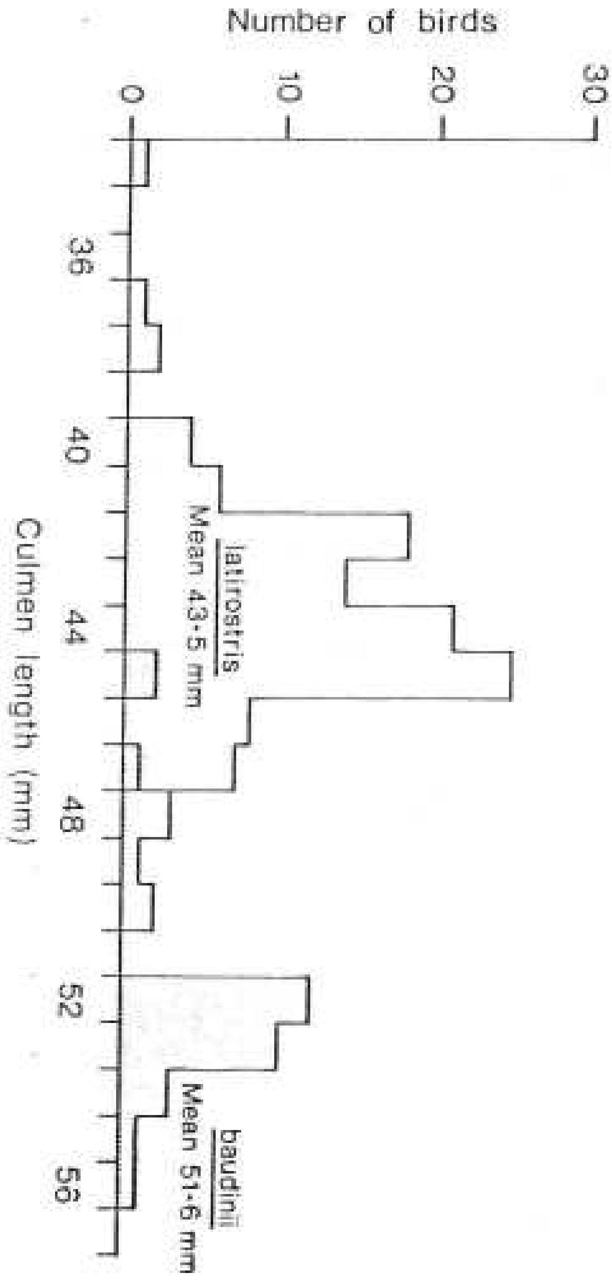


Figure 13. Length of culmen of 36 immature *baudinii* and 107 immature *latirostris* specimens. Both sexes represented.

extrapolation is borne out by two immature individuals of *baudinii* which had culmens of 45 mm in length; one was a male (540 grams) and one was a female (560 grams) and both were amongst the smallest of the sample (mean 620 grams with a range of 540-770 grams).

The rhamphotheca or horny covering of the maxilla grows throughout the life of the bird. In parrots it is constantly ground down and honed by chewing at objects, by feeding and by grinding the lower mandible against the ridges inside the maxilla. The result of these actions is that the culmen may change in length slightly during the life of the bird, depending on differing diets at certain stages, or due to damage to part of the structure (as mentioned earlier).

This might have meant that the difference in length of culmen between *baudinii* and *latirostris* was merely the result of differences in diet due to different ranges, rather than an evolutionary adaptation resulting from different diets (as suggested by Saunders 1974c).

In order to test this hypothesis the rhamphotheca was removed and the bone of the culmen (rostrum) measured. The distribution of length of rostrum of 17 adults of *baudinii* (8 males and 9 females) and *latirostris* (10 males and 7 females) is shown on Figure 14. In this case there is no overlap in the ranges and separation is complete.

The difference in the shape of the bill is emphasised by the differences in length of the inner tip of the maxilla. The distribution of these measurements from 20 adults (14 males and 6 females) and 10 immatures (5 males and 5 females) of *baudinii* and 19 adults (11 males and 8 females) and 11 immatures (2 males and 9 females) of

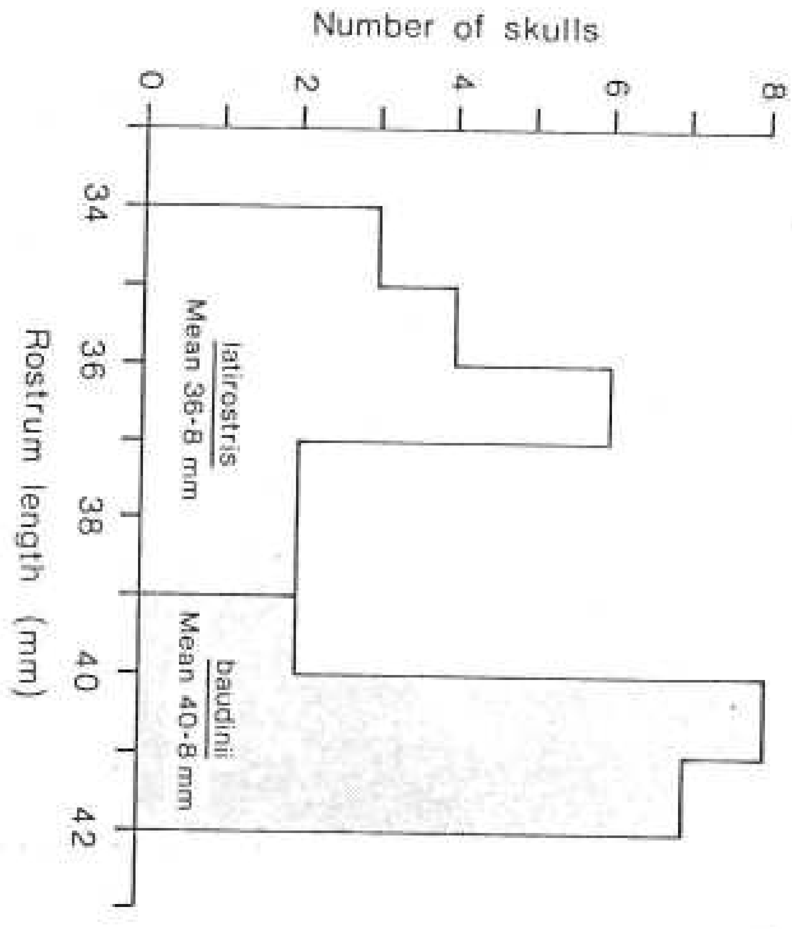


Figure 14. Length of rostrum in 17 adult baudinii and 17 adult latirostris. Both sexes represented.

latirostris is shown on Figure 15. The mean length for the 30 individuals of baudinii was 21.6 mm against a mean of 11.9 mm for the latirostris. In this case also, there was no overlap in the ranges, there being a 6.4 mm difference between the longest specimen of latirostris (13.3 mm) and the shortest of baudinii (19.7 mm).

4.3.2 Differences in food. The difference in food taken by baudinii and latirostris is shown in a sample of both collected from Mundaring Forest, 33 km east of Perth, between April 1971 and October 1972. The results of this sample are shown on Table 4. This sample is particularly informative because it was collected over an area where the same foods were available to both baudinii and latirostris at the same time. Despite this, both displayed differences in preference.

Baudinii concentrated mainly on the seeds of the Marri, Eucalyptus calophylla and insect larvae, especially those of wood-boring insects. Latirostris depended largely on the seeds of Pinus, of which there are several species growing in plantations scattered through the western half of the forest. They also concentrated on the seeds of Dryandra and Hakea species, both of which have seeds in small hard fruits which require considerable force to open. This preference for seeds of the Proteaceae is confirmed by studies of latirostris at Coomallo Creek and Manmanning (see sections 6.2 and 6.3). In these areas the birds feed almost exclusively on native vegetation, especially the seeds of Hakea, Grevillea, Dryandra and Banksia, there being no Pinus species in either area.

Although baudinii and latirostris both attack Marri fruit, they do

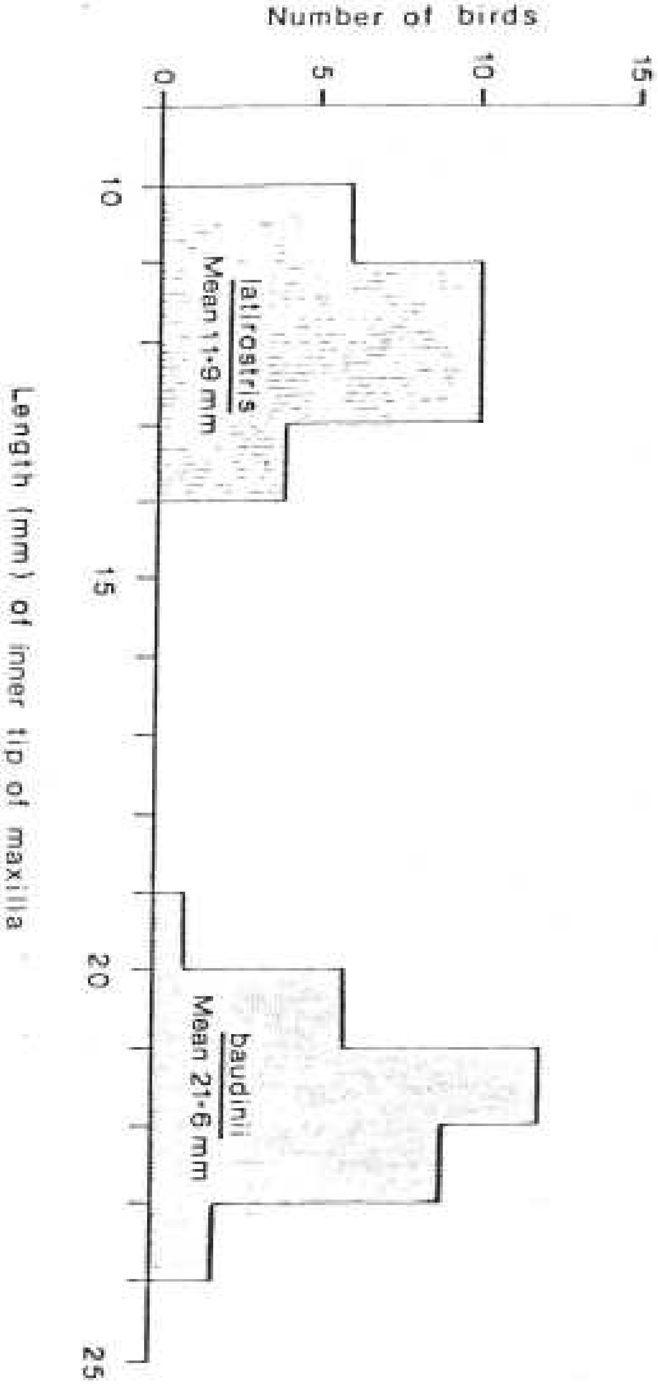


Figure 15. Length of inner tip of maxilla in 20 adult and 10 immature *baudinii* and 19 adult and 11 immature *latirostris*. Both sexes represented in each age class.

TABLE 4

Analysis of crop contents of cockatoos collected in Mundaring forest from April 1971 - October 1972. Values are the percentage of crops that contained more than five examples of each food (from Saunders, 1974c).

Food	*baudinii*	*latirostris*
Pinus spp. seed	0	81
Marri (*Euc. calophylla*) seed	89	8
Banksia spp. seed	5	5
Dryandra spp. seed	3	20
Hakea spp. seed	6	19
Insect larvae	16	0
Jarrah (*Euc. marginata*) seed	3	3
Unidentified seed	2	5
Number of crops examined	58	59

so in different ways (Saunders 1974c) and to a completely different degree. Marri appears to be the most important single species in the diet of *baudinii* (Table 4) and this is confirmed from observations of groups of *baudinii* feeding over their entire range (Table 5). The distribution of *baudinii* during the period when they were not nesting appeared to be tied to that of Marri.

In Table 5, 5 of the 34 feeding observations made of groups of *baudinii* showed that the birds were feeding on the seeds of *Erodium sp*. This is an exotic weed occurring in pastures and along cleared road and railway verges. The birds eat it when it sets seed between September and November. Once the seed sets the birds eat it until it dries up about 3 to 4 weeks later. Despite its limited availability, *baudinii* readily feeds on it when it is available, as does *latirostris*.

Both *latirostris* and *baudinii* move readily to ground to feed on *Erodium* and fallen fruit, e.g. Marri fruits that have been chewed off and dropped before the seeds have been extracted.

4.3.3 *Differences in calls*. The loud flight or contact calls of *baudinii* differ from those of *latirostris*. In order to investigate the difference, eight adult females and six adult males of *latirostris* and five adult males of *baudinii* were each, in turn, isolated in a cage at CSIRO, Helena Valley laboratories. The total vocal output for each individual from 1700 to 1830 on each of three days was recorded on a Sony TC 800B tape recorder via a Beyer M100 microphone.

The contact calls were chosen for analysis as they were uttered more frequently and they are the calls used to communicate with other

TABLE 5

Species used by baudinii as food based on observations of feeding groups throughout their range. Values are number of observations in which food was consumed. In some instances several different foods were consumed.

Food	Number of observations
Marri (Euc. calophylla) seed	31
Banksia spp. seed and/or flowers	6
Erodium spp. seed	5
Insect larvae	2
Total number of groups observed*	34

* Group size ranged from 2 - 200+ birds.

individuals when they are out of sight but within vocal range. The number of contact calls uttered by each individual over the four and a half hour period ranged from 13-112. All of the calls uttered by individuals making 20 calls or less in the period were used in the analysis. Those individuals producing more than 20 calls had 20 randomly selected for analysis. These calls were recorded on sonograph tracings using a sonograph Model Recorder (Kay Electric Co.) set on a narrow-band (45 Hz) filter. Sonographs of a total of 99 *baudinii* and 260 *latirostris* calls were made.

From examinations of the sonographs it appeared that each call consisted of four segments and from these segments a total of nine parameters were measured. A sonograph of a representative call from a *baudinii* and *latirostris* male is shown in Figure 16. The parameters that were measured are also indicated on this figure. These were: (i) total length of the call (seconds); (ii) duration of segment "A" (seconds); (iii) start frequency of segment "A" (kHz); (iv) duration of segment "B" (seconds)' (v) top frequency of segment "B" (kHz); (vi) duration of segment "C" (seconds); (vii) start frequency of segment "C" (kHz); (viii) duration of segment "D" (seconds); and (ix) start frequency of segment "D" (kHz).

The means, ranges and the results of comparisons between the means for each parameter in *baudinii* and *latirostris* are shown on Table 6. In seven of the parameters *baudinii* was significantly different from *latirostris*. There was no difference between them in the starting frequency of segment "C" or the duration of the last segment of the call (segment "D").

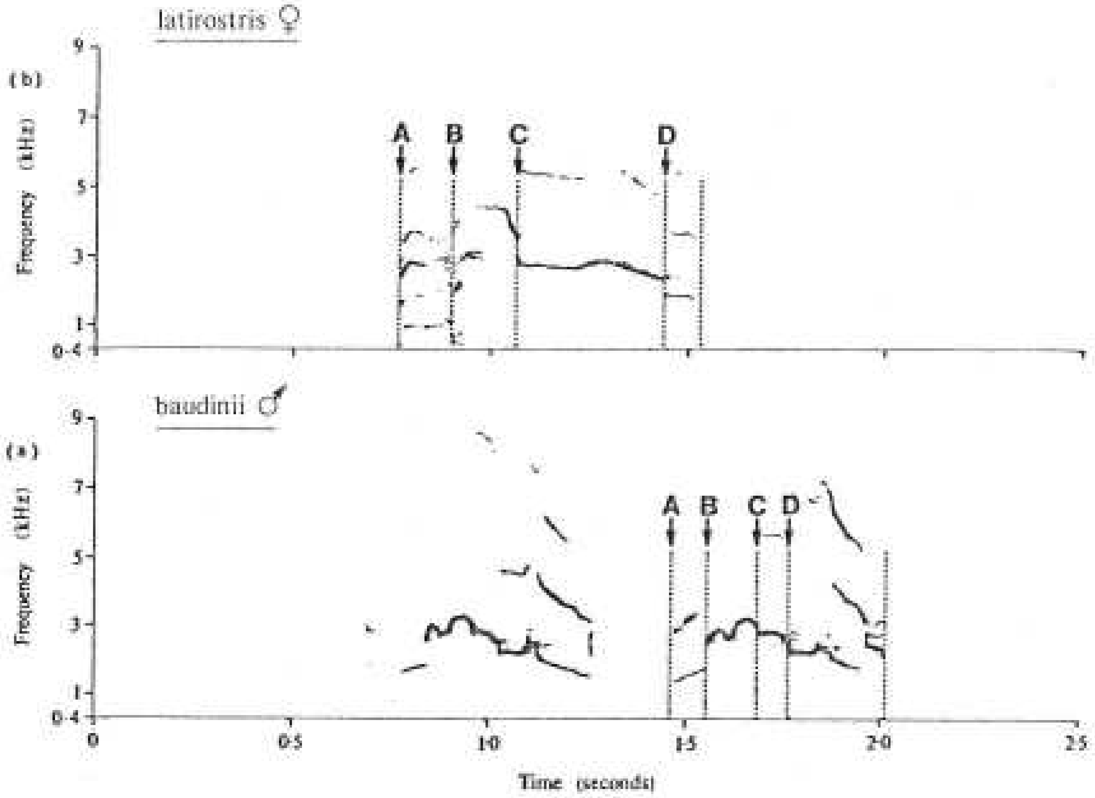


Figure 16. Sonograph of contact calls of (a) *baudinii* male and (b) *latirostris* female. The nine parameters examined are indicated in each call: start frequency of segments "A", "C" and "D"; top frequency of segment "B"; lengths of segments "A", "B", "C" and "D"; and the total length of the call.

TABLE 6

Comparisons between means of 9 parameters from contact calls of adult *baudinii* and *latirostris*

Parameter	Mean [Range]		Comparison of means		Coefficient of variation*	
	baudinii	*latirostris*	Value of "t"	Significance	*baudinii*	*latirostris*
Total duration of call (seconds)	.47 .35-.62	.64 .49-.81	22.4	.001 > P	13	12
Segment "a": Duration (seconds)	.10 .05-.19	.12 .01-.17	3.38	.001 > P	29	36
Start frequency (kHz)	1.26 .70-1.50	0.87 .70-1.50	17.25	.001 > P	15	23
Segment "b": Duration (seconds)	.12 .07-.18	.14 .03-.34	4.22	.001 > P	21	49
Top frequency (kHz)	3.11 2.90-3.40	3.72 2.40-4.60	19.93	.001 > P	4	12
Segment "c": Duration (seconds)	.06 .03-.13	.21 .09-.39	5.63	.001 > P	31	42
Start frequency (kHz)	2.53 2.20-2.80	2.54 2.40-3.00	0.61	Not sig.	6	5
Segment "d": Duration (seconds)	.18 .10-.25	.17 .05-.39	1.66	Not sig.	28	48
Start frequency (kHz)	1.93 1.70-2.20	1.81 1.50-2.20	8.96	.001> P	6	6
Number of individuals in sample	5 males	6 males 8 females				
Total number of calls analysed	99	260				

* Standard deviation divided by the mean expressed as a percentage.

The coefficient of variation is also shown for each parameter for both baudinii and latirostris on Table 6. The coefficient is obtained by dividing the standard deviation by the mean and expressing the answer as a percentage. It is an expression of the variance of the sample.

The length of the call and those four parameters involving segment frequency have the lowest coefficients and, therefore, the lowest variance. The four parameters involving segment duration have high coefficient values indicating that there is much more variability in these parameters.

The data presented in Table 6 have been analysed in detail and the results are fully presented in the section on vocalisation later in the thesis (section 9.5.3). A discussion on the variability in the sample is given in that section but one point that must be borne in mind when looking at the summary results in Table 6 is that the variability comes from several sources. Calls from one individual vary because there is normal variation in uttering the call or because the call conveys different information; there is variation between one individual and another (it is known that an individual is able to recognise another from its call [section 9.5.3]); variation due to sexual difference and possibly; variation due to differences in areas of origin.

The sample of latirostris totalling fourteen individuals is comprised of adults of both sexes and from at least four different areas ranging from one about 60 km north of Albany to one about 200 km north of Perth. The sample of baudinii consists of only five individuals of the same sex, which were all collected from the same foraging group. The higher coefficients of variation in the latirostris sample are probably due to variation introduced by sex and region.

The mean total length of the contact call in 5 adults of baudinii was 0.47 (SE 0.01; range 0.35-0.62) seconds and 0.64 (SE 0.01; range 0.49-0.81) seconds for 14 adults of latirostris, a difference of 0.17 seconds (36% of length of the call of baudinii). The mean duration of segment "C" was 0.21 (SE 0.007; range 0.09-0.39) seconds in latirostris and 0.06 (SE 0.002; range 0.03-0.13) seconds in baudinii, a difference of 0.15 seconds (250% of length of segment "C" in baudinii). It appears that the difference in length of the calls is due to the difference in duration of segment "C" and there is very little overlap in the ranges of value for either form.

The relation of total length of call and duration of segment "C" is shown in Figure 17 in which the duration of segment "C" is plotted against the total length of the call for each call analysed. In addition, a contact call from each of six individuals of baudinii (sex and age not known) was analysed from tape recordings made in the field in an area about 160 km south of where the five captive males of baudinii were collected. The data from these six calls are also shown on Figure 17 and are all within the cluster of points from baudinii calls recorded in the aviary. Figure 17 shows that, with increasing length of segment "C" there is an increase in the total length of the call.

Points for baudinii are clustered together at the lower end of the graph and there is little overlap with the much more widely scattered points for latirostris.

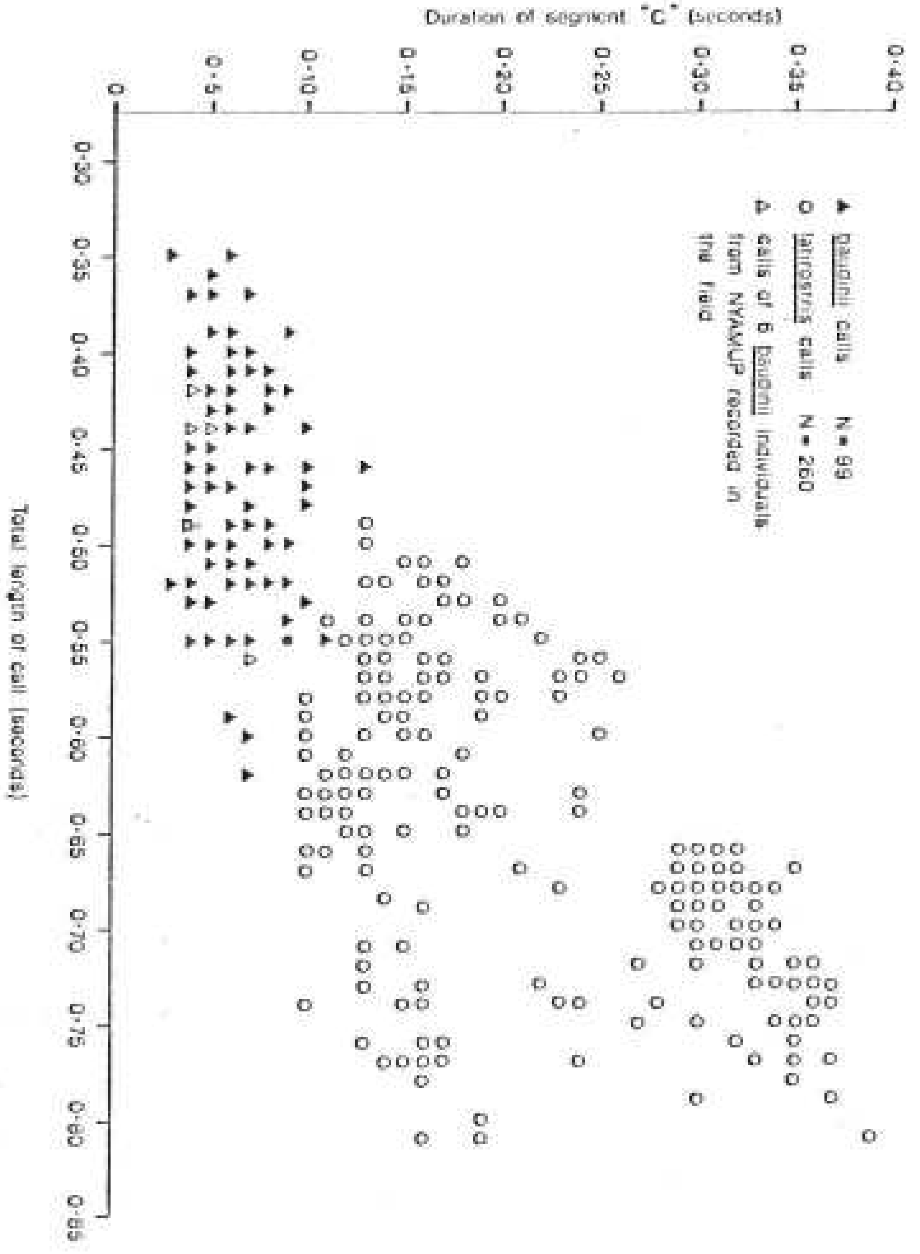


Figure 17. The length of segment "C" plotted against the total length of call for each call analysed.

The difference in duration of segment "C" and its general effect in altering the total length of the call is audible and, together with the other minor differences in duration and frequency, account for the difference between the contact calls. The calls are so markedly different that an experienced listener is able to identify a bird of either form on the call alone.

4.3.4 Distribution. The distribution of baudinii and latirostris is shown on Figure 18. This figure is based on observations and collected specimens. Also shown on this figure are the known nesting distributions of the two forms. Saunders (1974c) gave a generalised account of the breeding distribution and suggested that only baudinii breeds south of Perth in the area receiving more than 750 mm annual average rainfall. This has been disproved with the discovery of nests of latirostris as far south as Bunbury. The only nests of baudinii discovered to date have been in the very far south of the forest within the range of the Karri (E. diversicolor) which is shown on Figure 18 together with the distribution of Wandoo (E. wandoo) (Churchill and Storr, pers. comm.). The breeding distribution of latirostris in the wetter parts of its range follows the distribution of Wandoo closely.

It appears from the distribution of known nests that baudinii breeds in the far south of WA in the area to which Karri is confined and during the non-breeding season the birds forage quite widely moving as far north as Mundaring, near Perth. The area over which they forage is still connected by extensive tracts of State Forest from Albany to an area just north of Mundaring. Calyptorhynchus latirostris breeds

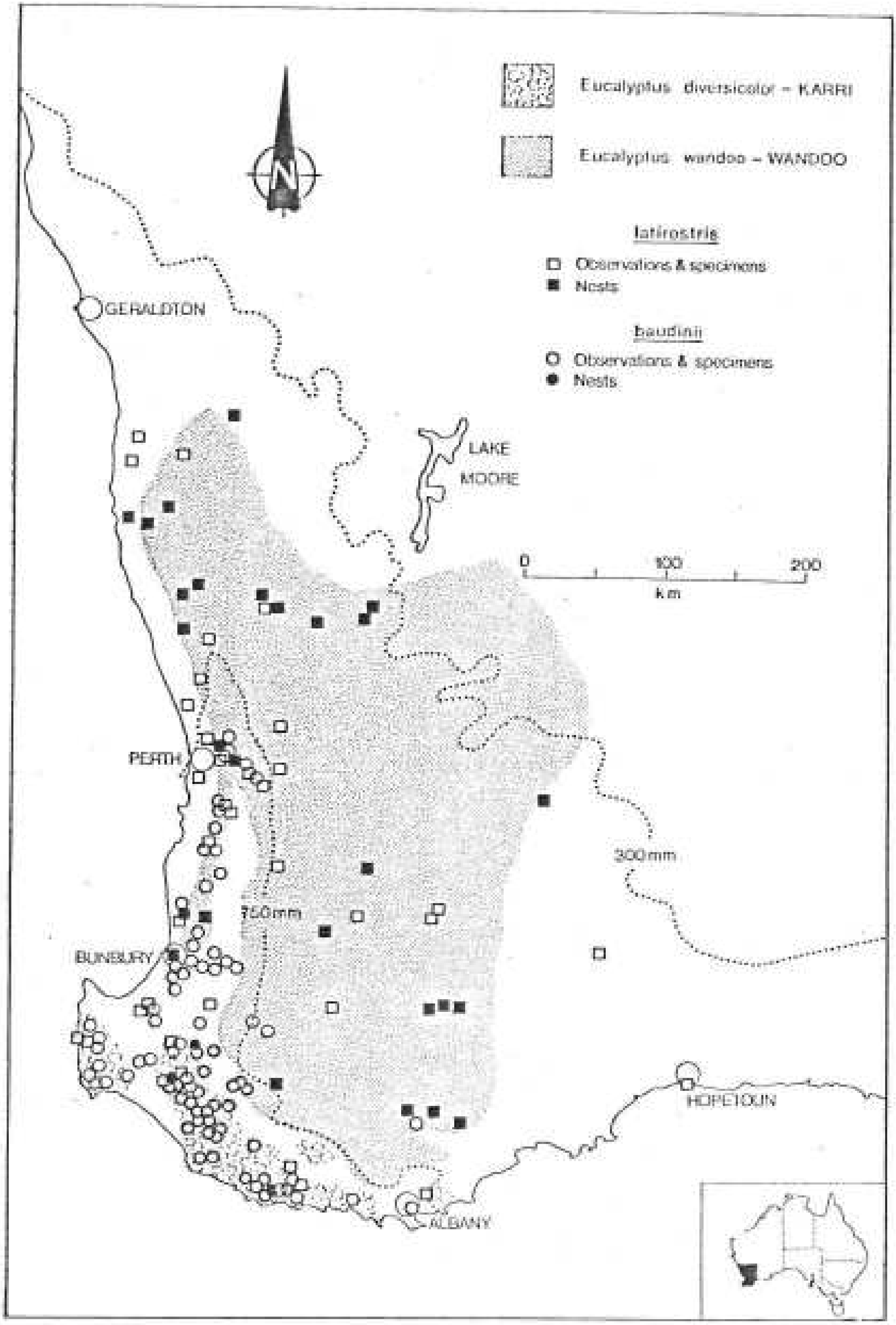


Figure 18. Distribution of the two forms of the White-tailed Black Cockatoo. The distribution of Karri and Wandoo are based on maps supplied by Drs. D.M. Churchill and G.M. Storr and used with their permission.

in the area outside this, following the belt of Wandoo down the coastal plain to Bunbury. These birds also wander widely following breeding and forage within the breeding range of _baudinii_, just as _baudinii_ does in part of the _latirostris_ range.

4.4 Yellow-tailed Black Cockatoo.

4.4.1 _Methods_. A total of one hundred skins of _C. funereus_ from all of the Australian museums were examined and from each skin the following measurements were taken:

Length of folded left wing
Length of tail
Length of exposed culmen
Width of maxilla at widest point
Length of inner tip of maxilla
Length of left tarsus
Length of claw on longest toe of left leg.

In addition to these measurements, the colour and size of the cheek patch and the colouring of the tail "windows" were noted with particular attention being paid to the intensity of the spotting on the yellow colouring of the tail.

Because some specimens lacked data, only ninety-four could be used in the analyses. Six were excluded because they had no collecting locality. Very few specimens carried adequate data, the sex of the specimen was frequently not stated and had to be determined by the colour of the bill and size of the cheek patch, and age was given on less than fifteen of the entire sample.

4.4.2 *Results*. Condon (1975) had divided *C. funereus* into two subspecies: *C. f. funereus*, a large form of the coastal forests of eastern Australia to extreme eastern Victoria; *C. f. xanthanotus*, a smaller form of southern Victoria, south-eastern South Australia and Tasmania. To assess this treatment of *funereus*, the specimens were grouped into regions from which they were collected and the measurements then compared within the regions for homogeneity. The regional groupings were: South Australia, Kangaroo Island and south-western Victoria (SA); Tasmania and the Bass Strait Islands (Tasmania); and New South Wales and Queensland (NSW). The locations of these regional groups are shown on Figure 19 which also shows the distribution of *funereus* based on collected specimens and records from the literature dating back to 1890.

Although many specimens had no sex indicated on the data sheets, it was possible to sex the specimens on colouring of the maxilla and cheek patch. Adult males have black maxillae and small dirty yellow cheek patches. Immature males have small dirty yellow cheek patches but the colouring of the maxillae may vary from dark grey to bone in colour (as in females). By colour of the maxillae, males could be separated into immatures and adults but, because immature females resemble adult females, it was not possible to age skins of females. Consequently the regional groupings were divided into sexes only for analysis.

The mean and range of values for each sex in each regional grouping for each of the seven characters measured are shown on Table 7. In the NSW and SA samples there are no differences in size between the sexes. This is also true of *baudinii* and *latirostris* (Saunders 1974c). In the sample from Tasmania, the females had longer tails and longer culmens

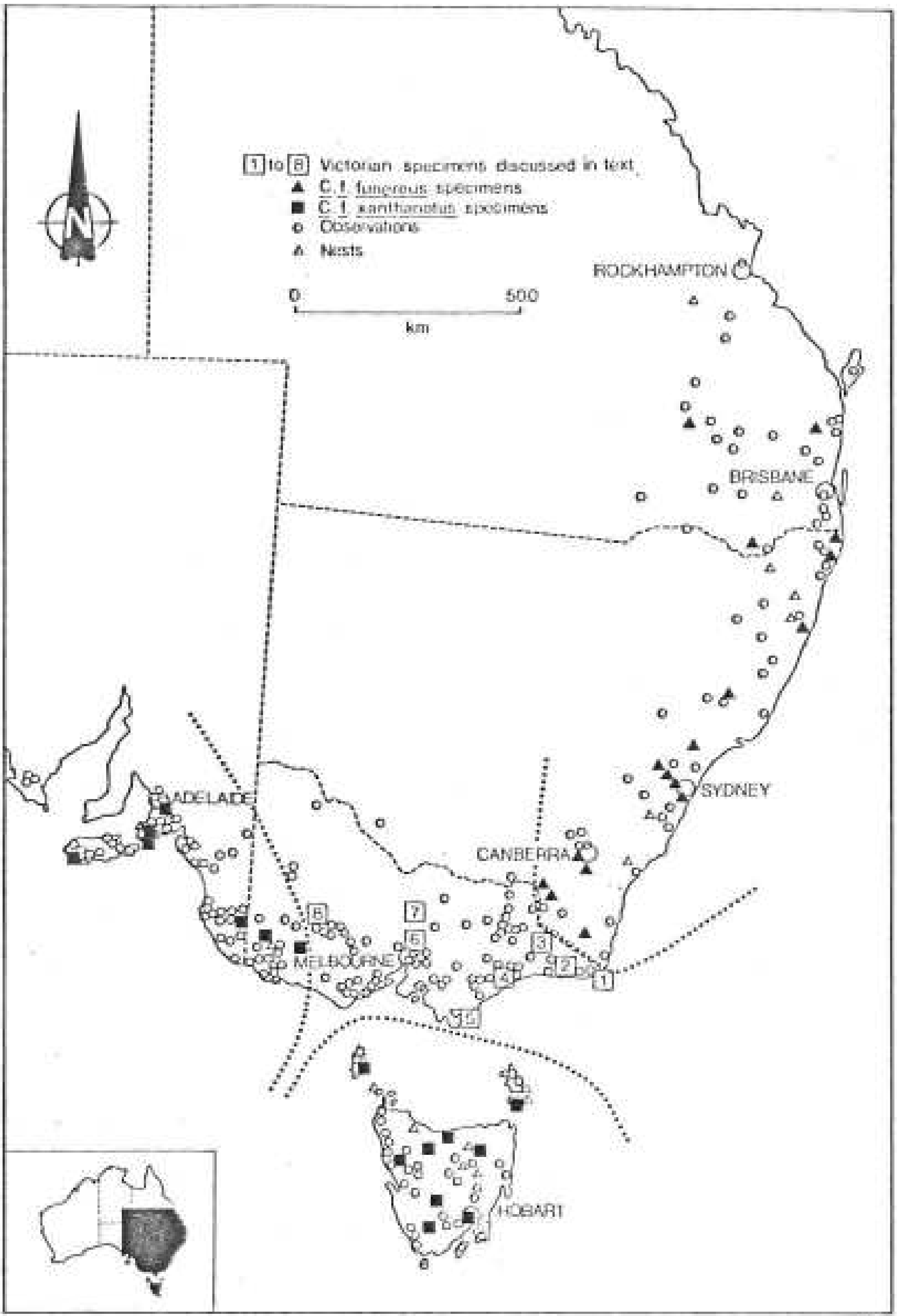


Figure 19. Distribution of the Yellow-tailed Black Cockatoo, based on information from the literature as well as specimens. The known breeding areas are also shown. Also shown are the subdivisions into three regional groupings in which the Museum material was examined and compared.

TABLE 7

Mean and range of values for seven characters for each sex in three regional groupings of *C. funereus*

	NSW and Qld		Difference between sexes	South Aust.		Difference between sexes	Tasmania		Difference between sexes
	♂♂	♀♀		♂♂	♀♀		♂♂	♀♀	
No. in sample	23	14		12	14		10	14	
Wing	418.8 (391-454	421.7 (389-452)	NS	370.2 (348-383)	364.7 (346-387)	NS	363.2 (345-393)	377.6 (353-393)	NS
Tail	351.5 (311-380)	358.5 (342-384)	NS	291.3 (275-315)	288.6 (240-312)	NS	292.8 (273-313)	311.1 (287-333)	.01>P>.002
Culmen length	49.3 (46.1-53.4)	49.2 (46.9-51.0)	NS	45.6 (41.3-49.2)	44.5 (42.6-47.3)	NS	46.1 (44.0-49.8)	48.7 (44.1-53.5)	.01>P>.002
Maxilla width	25.0 (23.0-27.0)	24.7 (23.6-26.3)	NS	23.0 (21.7-25.4)	22.3 (20.0-24.0)	NS	23.5 (21.0-24.8)	24.0 (21.7-26.9)	NS
Maxilla inner tip	13.2 (9.6-15.2)	12.4 (8.1-15.1)	NS	12.7 (10.0-15.2)	11.7 (10.6-13.3)	NS	12.2 (8.8-14.5)	13.8 (12.0-16.0)	.02>P>.01
Tarsus	38.4 (34.6-41.0)	38.5 (35.2-41.7)	NS	36.2 (34.1-37.5)	35.6 (30.0-38.7)	NS	34.3 (28.1-38.6)	35.9 (31.0-39.9)	NS
Claw	20.5 (19.0-22.7)	20.2 (18.0-22.4)	NS	18.5 (16.2-20.8)	18.4 (17.0-20.5)	NS	18.3 (13.2-21.3)	18.9 (12.9-21.5)	NS
% adult males in sample	61%	-		67%	-		40%	-	

than males. The sample of males from NSW consisted of 61% adults and the sample from SA had 67%, yet the sample from Tasmania had only 40%. Adults of both baudinii and latirostris are larger than the immatures and it is reasonable to assume that this is also true of funereus. The inclusion of more immatures in the sample of males from Tasmania, together with the possibility of more adults than immatures in the sample of females may have biased the sample from Tasmania compared with the other samples. Because there is no way of aging the females, it was not possible to verify this point.

The sex classes in each regional grouping were combined except for those characters in the sample from Tasmania where there were significant differences between sexes. Then the group from NSW was subdivided into two regional sub-groupings. One contained those collected in NSW south of a line drawn due west of Sydney and the other contained those collected north of this line. There was no significant difference between the mean values for either sub-grouping in any of the seven characters. This indicates that there is no demonstrable cline in size in that state, based on the material available.

The measurements for the seven characters in each regional group are shown on Table 8. In the sample from Tasmania where the sexes differed in size only the values for the males are presented. With each mean a value which represents 1.3 times the standard deviation is given. This designates the range of measurements within which 90% of the population would occur. If the measurements indicated do not overlap when comparing different populations, then subspecific separation may be justified. Subspecies are delineated here following Mayr (1963) who defined the subspecies as 'an aggregate of local populations of a species, inhabiting a geographic subdivision of the range of the species, and

TABLE 8

Mean and range of values for seven characters for combined samples of *C. funereus* from the regional groupings. The mean is followed by a figure which represents 1.3 times the standard deviation of the sample. Measurements for *latirostris* and *baudinii* are also given. The results of statistical tests between means of different groupings also indicated.

	funereus							
	NSW/QLD	Difference in mean values of NSW/QLD and Tas. populations.	TASMANIA	Difference between mean values of Tas. & SA populations.	SOUTH AUST.	Difference in mean values between SA populations and *latirostris*	*latirostris*	*baudinii*
No. in sample	37		24		26		293	102
Wing	419.9 ±21.6 (389-454)	.001>P	371.6 ±21.1 (345-393)	NS	367.2 ±15.6 (346-387)	NS	364.1 (339-393)	379.4 (352-400)
Tail	354.2 ±23.2 (311-384)	.001>P	ϕ292.8 ±16.4 (273-313)	NS	289.8 ±20.5 (240-315)	NS	283.2 (220-315)	288.8 (260-330)
Culmen length	49.2 ± 2.5 (46.1-53.4)	.001>P	ϕ46.1 ± 2.3 (44.0-49.8)	NS	45.0 ± 2.6 (41.3-49.2)	.001>P	44.0 (37-47)	52.5 (45-57)
Maxilla width	24.9 ± 1.2 (23.0-27.0)	.001>P	23.8 ± 1.7 (21.0-26.9)	.002>P>.001	22.7 ± 1.5 (20.0-25.4)	NS	22.2 (20.0-25.0)	21.6 (19.0-24.0)
Maxilla inner tip	12.9 ± 1.9 (8.1-15.2)	NS	ϕ12.2 ± 2.4 (8.8-14.5)	NS	12.2 ± 1.7 (10.0-15.2)	NS	11.9* (10.1-13.1)	21.6* (19.7-23.4)
Tarsus	38.5 ± 1.9 (34.6-41.7)	.001>P	35.2 ± 3.6 (28.1-39.9)	NS	35.9 ± 2.2 (30.0-38.7)	NS	37.0* (34.0-39.4)	36.5* (34.4-38.4)
Claw	20.4 ± 1.4 (18.0-22.7)	.001>P	18.6 ± 3.2 (12.9-21.5)	NS	18.5 ± 1.4 (16.2-20.8)	.001>P	19.5* (17.5-21.6)	21.1* (17.9-22.9)

* Sample size = 30
ϕ only ♂♂ used: sample size = 10

differing taxonomically from other populations of the species.' He further stated that 'subspecies are to be named only if they differ "taxonomically", that is, by diagnostic morphological characters.' In determining the degree of difference in morphological characters between subspecies, I have followed Rowley (1970) who used the term subspecies to describe geographically defined aggregates of local populations, 90% of which differ in morphological characters from 90% of other such subdivisions of the species.

The males from Tasmania were wider in the maxilla than the birds from SA, there being no other significant differences (Table 8). Despite the significant difference between the means for this character, a large part of both populations fell within a range of values common to both and so there seems to be no basis for separating the two populations. Although the females from Tasmania had longer tails and longer culmens than the males and the birds from SA, this point was true of them as well. Thus, the birds from Tasmania and southern Australia are of the same form but differ slightly as a result of isolation in different geographical ranges.

Birds from eastern Australia had much longer wings and tails and were larger in the maxillae (both length and width), tarsi and claws than birds from Tasmania and southern Australia (Table 8). In measurements of both wing and tail there is no overlap at the 90% level between the birds from NSW and the other two populations (only 3 out of 37 [8%] overlapped the range of the birds from Tasmania). In the other characters a large part of all populations would fall within a range of values common to all.

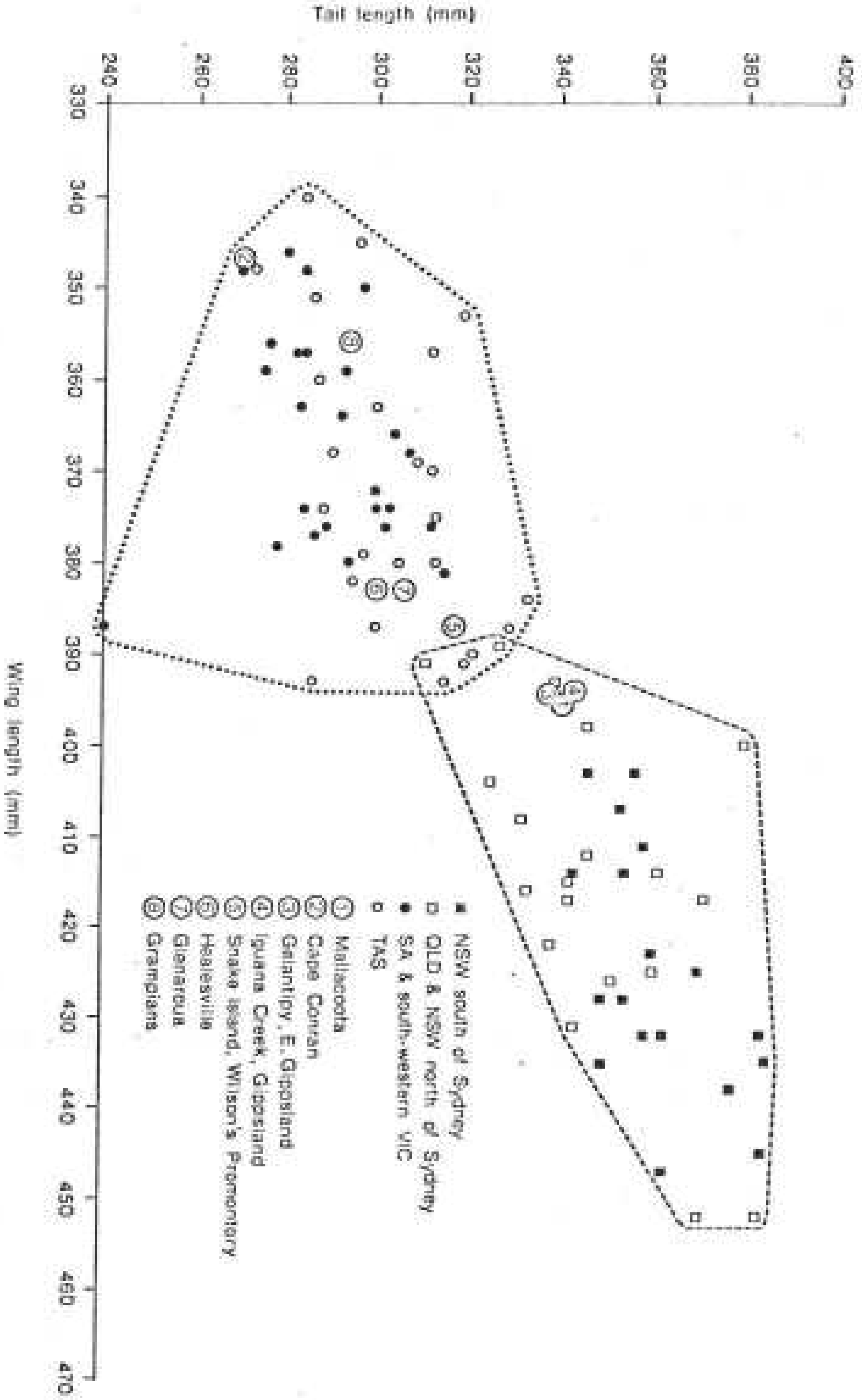
For comparative purposes the mean and range of measurements for the seven characters for *baudinii* and *latirostris* are also shown on Table 8. *Calyptorhynchus latirostris* is the same size as *funereus* from SA except for a slightly shorter culmen and a longer claw. The shape of the maxilla of *latirostris* is similar to the shape of the maxillae in all three regional groupings of *funereus* but *baudinii* has a much larger maxilla of a completely different shape from all of the others.

To illustrate further the similarity between the birds from Tasmania and SA and the differences between them and the birds from NSW, the length of the tail of each specimen was plotted against the length of its wing. The resulting graph is shown on Figure 20 and the NSW points form a cluster which barely overlaps the cluster formed by the Tasmanian and SA points.

The regional groups of SA and NSW meet somewhere in central and south-eastern Victoria, but unfortunately there were only eight skins collected from this region. The location of each of these skins is shown on Figure 19 and it was hoped that an examination of these specimens would show if they were sharply separated or whether they integrated where they approached each other geographically. Each of the eight specimens is plotted on the wing/tail graph on Figure 20. Birds from Mallacoota and Gippsland fall within the cluster from NSW (1, 3 and 4) while birds from the Grampians, Glenaroua, Healesville, Cape Conran and Snake Island (8, 7, 6, 2 and 5) fall within the cluster from SA. Only the birds from the Grampians, Glenaroua and Healesville could definitely be classed as adults, the bird from Cape Conran was an immature male and the remainder were females, and so, impossible to age.

The breeding distribution of *funereus* is shown on Figure 19 and is based on information obtained from the literature and egg collections.

Figure 20. Length of the tail of each *C. funereus* specimen plotted against the length of its wing. Also shown individually are the eight Victorian specimens not included in regional groupings in the analyses.



The laying period is: November to January in South Australia, Victoria, Tasmania and the Bass Strait Islands; December to February in southern NSW; January to May in northern NSW; and April to July in the extreme north of the range.

The usual clutch is of two eggs (12 out of 16 clutches from museums were of two) and the size of the eggs is shown on Table 9. The size of eggs of latirostris is also shown. In latirostris the egg of a single egg clutch is the same size as the larger egg of a two-egg clutch, and these eggs are significantly larger than the smaller egg of the clutch (section 5.4.3). For this reason those eggs in the single egg clutches have been analysed together with the larger egg of the two-egg clutch. Clutches of C. funereus have been analysed in regional groupings and there is very little difference in size of eggs within the species.

Although the usual clutch is two, the birds raise only one chick, the second nestling dying soon after hatching. This is reported in Forshaw (1969) and is often quoted for both Yellow-tailed Black Cockatoos and White-tailed Black Cockatoos. It is not unusual for latirostris to fledge both nestlings (section 5.6.2.8) and there is a note attached to one clutch of eggs in the H.L. White Collection which indicates that funereus is also capable of fledging both. The note states that on Cape Barren Island, two very large nestlings were seen late in May in a hollow. From the date they must have been close to fledging.

Throughout its range funereus feeds on the seeds of the

TABLE 9

Egg measurements of *C. funereus* and *latirostris*. No data are available for *baudinii*. Single egg clutches have been included in analyses by combining them with the larger egg of a two-egg clutch. Values are the mean measurement and the range is shown in brackets.

		funereus		*latirostris*	*baudinii*
	NSW-QLD	TASMANIA	SOUTH AUST. & SW VIC.		
Larger egg	49.4 x 35.8 (46-53) (35-36) N = 4	47.4 x 35.0 (45-50) (33-37) N = 6	48.3 x 35.2 (46-53) (34-36) N = 6	48.6 x 34.7 (44-54) (31-41) N = 76	No Data available
Smaller egg	only 1 in sample	45.2 x 34.8 (44-48) (34-36) N = 6	44.8 x 33.2 (40-49) (32-34) N = 5	45.7 x 34.1 (40-51) (32-40) N = 41	

Proteaceae and on insect larvae infesting acacias, eucalypts, casuarinas, grass-trees (Xanthorrhoea). McInness and Carne (1978) have an excellent review and account of predation of Yellow-tailed Black Cockatoos on insect larvae particularly the cossid moth larvae. It also feeds on seeds of the introduced Pinus spp. This diet is not unlike that of latirostris.

4.5 Discussion.

4.5.1 Yellow-tailed Black Cockatoos. The relationship of the two white-tailed Black Cockatoos to each other and to the yellow-tailed Black Cockatoos is linked with evolution in the C. funereus superspecies. Within funereus there are two forms: one, a smaller form in South Australia (including Kangaroo Island), western Victoria, Tasmania and the Bass Strait Islands; and the other, a larger bird occurring from southern Queensland to Gippsland. Both forms are similarly sexually dimorphic in colour and individuals of both have the same varying degrees of brown/black spotting and barring on the tail "windows" ranging from light spotting to very heavy spotting that runs together to form heavy barring. There appears to be no difference between the sexes in this character, and no basis for saying that females are more heavily spotted or barred than males as mentioned by Forshaw (1969).

There is a wide gap between the known breeding ranges of the two forms (Figure 19) which makes it likely that birds found in this gap are non-breeding wanderers. On present evidence it seems likely that there are two subspecies in C. funereus (Condon, 1975) and that their ranges as given by Condon are accurate as indicated by this study (see Storr [1973] for range in Queensland). More information is needed on the ecology, behaviour, movements and an adequate collection of material would be needed from the area east of Melbourne to establish the ranges and if there is a grading of one form into the other. C. funereus funereus Shaw is the larger form confined to eastern Victoria and ranging north and C. f. xanthanotus Gould is the smaller form from Victoria, South Australia and Tasmania. There may be small differences between the forms from Tasmania and the mainland due to geographical isolation.

4.5.2 White-tailed Black Cockatoos. The fact that baudinii and latirostris have different shaped maxillae, different cranial morphology, different preferences of food and different contact calls indicates that the two forms have been isolated for some time. The question of their taxonomic status remains. If they are subspecies, their breeding ranges would be allopatric and hybrids might be expected to occur in the zone of overlap. Unfortunately there were not enough nests of either form found to clarify this point. Individuals with lengths of culmen intermediate between the two forms ought to indicate hybridisation but the distribution of length of culmen in both forms did not show any departure from a normal distribution and there was no overlap in length of rostrum or in the length of the inner tip of the maxilla.

These morphological differences which provide complete separation of the two forms together with the other differences indicate that the forms are specifically distinct.

4.5.3 Relationship between the Yellow-tailed and White-tailed Black Cockatoos. What then is the relationship between funereus and the two White-tailed Black Cockatoos? There are only minor differences in size between latirostris and funereus from SA (Table 8) and these are connected with the length of the culmen, that of latirostris being slightly shorter, though the bills of both are alike in shape. The diets are also similar and the major difference between them is in colour, the yellow being replaced by white and loss of the spotting. It was not possible to obtain suitable material in order to examine the contact calls of funereus to establish if it is similar to the contact call of latirostris.

In view of the many similarities between allopatric latirostris and funereus, it seems reasonable to treat latirostris and funereus as subspecies. Their separation in south-west and south-eastern Australia respectively may be relatively recent. On the other hand, the greater differences between baudinii and latirostris probably reflect a much older separation, even though the two forms are geographically contiguous now.

It seems likely that the ancestral stock of baudinii was originally part of a population of proto-funereus that once extended right across southern Australia and was subsequently cut off during the late Pliocene or early Pleistocene, that separated the Bassian floras and faunas in south-Western and south-eastern Australia. During this period baudinii became adapted to a diet of Marri. During isolation its yellow pigmentation may have been lost and replaced by white, but the reason for this is not clear. Calyptorhynchus latirostris probably evolved from a subsequent invasion of the south-west by funereus during one of the more favourable periods of the Pleistocene when eastern and western Bassian faunas were reconnected across the head of the Great Australian Bight. This population did not invade the far south-west (which was already occupied by baudinii) and remained in the habitat that was similar to that which it had occupied in the east. This population, in response to the same climatic conditions to which baudinii was responding, also lost its yellow colour and spotting. Some individuals of both baudinii and latirostris have yellow ear patches and feather margins and some have varying degrees of yellow in the tail "windows". Of 52 nestlings of latirostris examined in 1973, 43 (83%) had varying degrees of yellow (from pale to bright yellow) on the ear patches. Most lose this colouring soon after leaving the nest. There are no comparable data on baudinii. This reconstruction of the origin of baudinii and latirostris by re-invasion has parallels in other Bassian species (see Serventy and Whittell 1967; Ford 1971).

The separation of the two populations may have been reinforced by a shortage of suitable hollows in which to nest. Breeding adults of latirostris return to the same area to breed each year and it is likely that baudinii does the same. This behaviour would help to maintain the separation even though there may have been an overlap in foraging ranges.

The distribution of Karri and Wandoo define the nesting distribution of baudinii and latirostris. Calyptorhynchus latirostris nests mainly in

Wandoo and Salmon Gum E. salmonophloia which occurs in the drier areas overlapping and extending beyond the range of Wandoo (section 5.1.4). Of five latirostris nests found inside the 750 mm rainfall area, three were in Wandoo, one in Tuart E. gomphocephala and one in Marri. Three baudinii nests were in Karri (two) and Marri (one).

Studies on selection of nest sites by latirostris have shown that the birds will use any hollow in a tree provided it is large enough and of the correct shape for their nesting purposes (section 5.1). At Tarwonga, Marri was the dominant tree with isolated patches of Wandoo in the valleys or on sandy areas. Here the birds nested exclusively in Wandoo, where, of 42 hollows measured and classed as suitable for use by black cockatoos, only one was in a Marri. Wandoo appears to be less resistant to fungus and termite attack (two major agents in the formation of hollows) than Marri or Jarrah E. marginata. Marri and Jarrah are the main woodland and forest trees occurring in the area between the distributional ranges of Karri and Wandoo. Neither appears to offer many hollows of suitable size or shape for use by black cockatoos. Lack of breeding sites in Marri or Jarrah forests may have been the barrier that prevented the invading population over-running the range of baudinii and perhaps replacing it.

The taxonomic conclusions drawn from this section are that the C. funereus superspecies comprises two species, one monotypic, the other of three subspecies, as follows:

Calyptorhynchus funereus (Shaw) Funereal* Cockatoo

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* Now that white-tailed latirostris is included in C. funereus, Yellow-tailed Black Cockatoo becomes inappropriate for this species.

Calyptorhynchus funereus funereus Shaw

Psittacus funereus Shaw, 1794. Nat. Misc. 6: Pl. 186, text - New Holland - New South Wales.

Coastal mountain forests of eastern Australia from Clermont (north-west of Rockhampton) and Fraser Island south through New South Wales to extreme eastern Victoria (Gippsland). A large form.

Calyptorhynchus funereus xanthanotus Gould

Calyptorhynchus xanthanotus Gould, 1838, Syn. Birds Aust. Append.: 5 - Tasmania.

Calyptorhynchus funereus whitei Mathews, 1912, Austral avian Rec. 1: 35 - Kangaroo Island.

Southern Victoria; south-eastern South Australia to Mt. Lofty Ranges, southern Yorke Peninsula, lower Eyre Peninsula north to Wanilla and Marble Range; Kangaroo Island: King, Flinders (formerly breeding) and Cape Barren Island, Bass Strait; Tasmania. A small form.

Calyptorhynchus funereus latirostris Carnaby

Calyptorhynchus baudinii latirostris Carnaby, 1948, West. Aust. Nat. 1: 137 - Hopetoun, Western Australia.

South-western Western Australia from lower Murchison River and south to beyond Esperance in the drier inland sandplain and Mallee areas. A small form with white ear patches and white tail "windows".

Calyptorhynchus baudinii Lear, Long-billed Black Cockatoo.

Calyptorhynchus baudinii Lear, 1832, Ills Psittacid. 12 - no locality; restricted to Albany by Mathews, 1913. Austral avian Rec. 1: 190.

Calyptorhynchus baudinii tenuirostris Mathews, 1913,
Austral avian Rec. 1: 190 - Wandering, Western Australia.
Extreme south-western forested corner of Western Australia.

There is no evidence for the choice of Albany as a type locality for C. baudinii by Mathews other than his opinion that it resembled a bird collected by Carter from Albany and that Baudin spent some time in King George Sound. It may well be restricted to Geographe Bay, another location Baudin sent a party ashore.

5. Breeding biology

5.1 Nest selection.

5.1.1 Nest hollow location.

With the start of the breeding season adult birds return to the breeding areas. These birds nest in hollows found in live or dead standing trees. The location of suitable nest hollows at Coomallo Creek and Manmanning is shown in Figures 3 and 4. The distribution of hollows in relation to surrounding cleared and uncleared land is also shown on these figures.

5.1.2 Nest hollow selection.

The histories of 56 tagged females that had bred at Coomallo Creek for at least two seasons, were examined to see if they used the same nest hollow each year. The result of this analysis is shown on Table 10; half the females did nest in the same hollow that was used previously. Those that used a different hollow even though their previous one was available were significantly less successful in fledging young than the others.

The hollows used by some of the individual females whose histories are known for at least two breeding seasons are shown in Figures 21 and 22.

The nest sites of 21 females out of a possible 63 that could have been used to illustrate this at Coomallo Creek and those of eight females out of a possible 16 at Manmanning are shown on Figures 21 and 22.

TABLE 10

Coomallo Creek : Hollow selection by tagged females

		Category	Successfully fledged young	Unsuccessful	Total	(%)
No. of ♀♀ that returned same hollow the following breeding season.		A	44	5	49	(51%)
No. of ♀♀ that moved to different hollow the following breeding season when:	Previous year's hollow not available.	B	20	7	27	(28%)
	Previous year's hollow was available	C	11	9	20	(21%)
No. of tagged ♀♀ in sample: 56	TOTAL		75 (78%)	21 (22%)	96	

No significant difference in success rate between Categories B and C $X^2_1 = 1.86$

Significant difference in success rate between Categories A and (B+C) $X^2_1 = 7.98$ $(0.01 > P > 0.001)$

Manmanning: Data were too limited for comparisons. Had data on only 11 tagged ♀♀

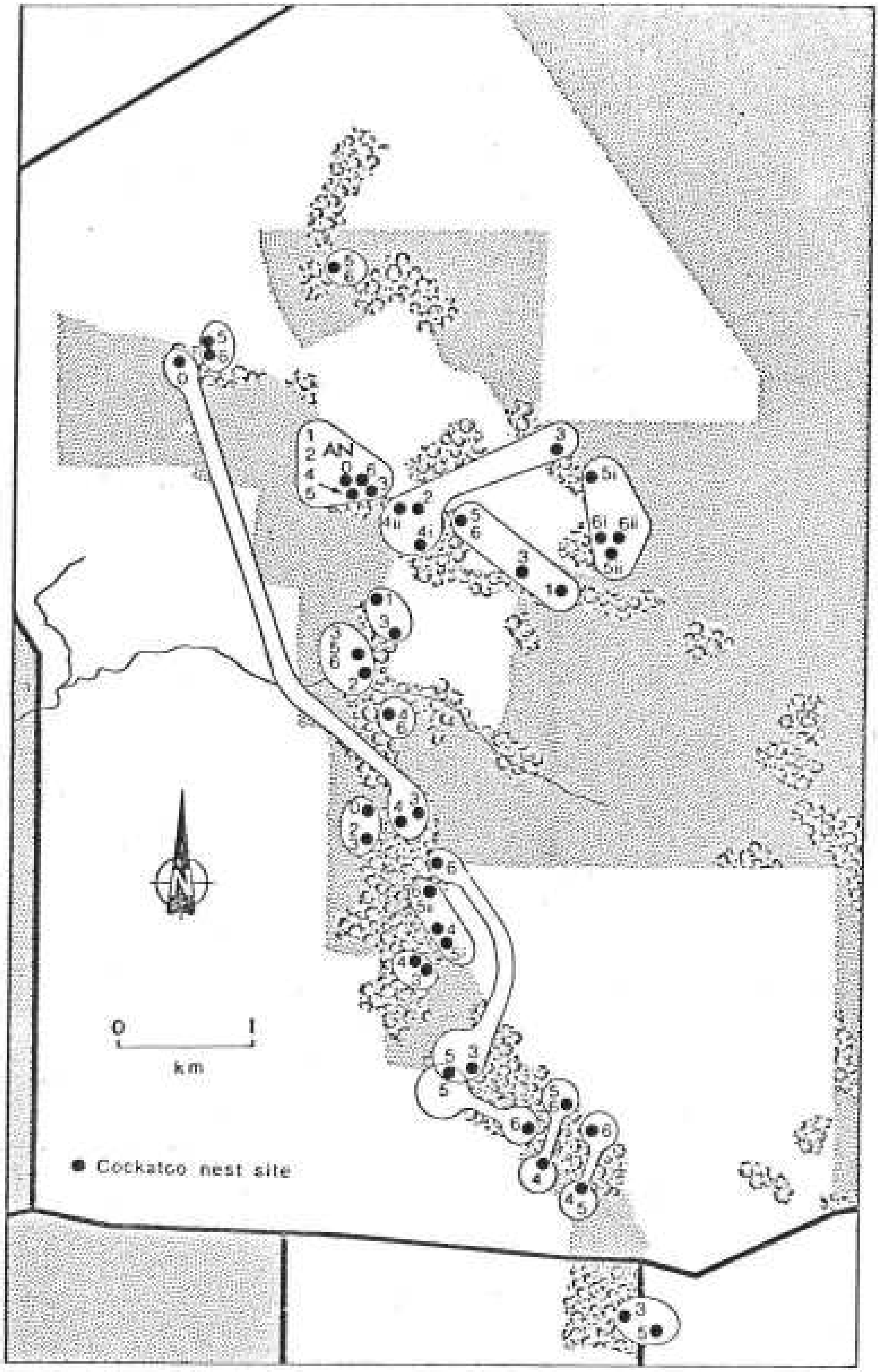

Figure 21. Coomallo Creek. Locations of nest hollows of 18 individual females (AN is discussed in the text). The number beside nest indicates year (e.g. 5 is 1975).

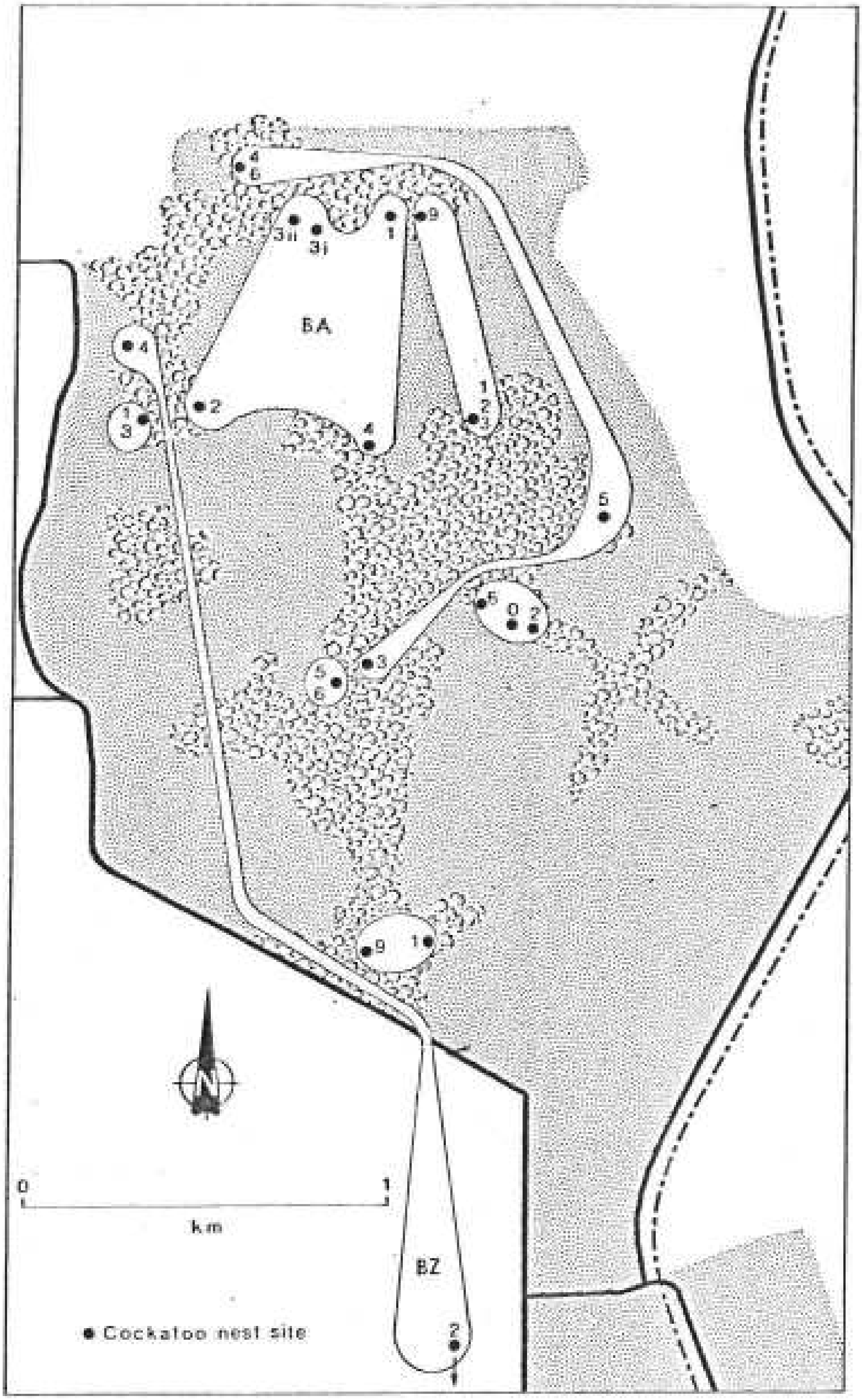

Figure 22. Manmanning. Locations of nest hollows of eight individual females.

In 51% of cases the females have used the same hollow each season or have used one in the same patch of woodland or in an adjacent one. At Coomallo Creek, AN is a typical example and in the seven breeding seasons she has used only four different hollows, one of them for four seasons and all the hollows were in the same patch of woodland. Only five out of the 63 known cases went further than the next patch of woodland.

Manmanning birds also follow this pattern. The only exceptions are females that nested in outlying areas and subsequently moved into the main nesting area; e.g. BZ in Figure 22.

5.1.3 Formation of hollows. Hollows are formed in trees as a result of various agents but the two most important are fungi and insects (Anon 1971). Fungi can attack the standing tree, or may gain entry through some injury to the tree, such as firescar or bough-break. A number of different species attack the heartwood and break down the wood cell structure. As this destruction takes place within the tree, wind-caused movement of the tree helps to compress the decayed matter, creating hollows. The breaking off of an infected bough then provides access to the hollow.

Insects, particularly termites, also contribute to hollow formation by attacking and eating out the heartwood, but of the two agencies, fungi appears to be the more important (Mr. R. Hilton, Univ. of W.A., pers. comm.).

Only mature trees are large enough to have hollows of suitable size for White-tailed Black Cockatoos, but some species of eucalypt are more susceptible than others. Wandoo, salmon gum and karri appear to be more extensively affected than other large species like jarrah and marri, and they are more commonly used for nesting.

5.1.4 Species of tree used as nest sites. The species of nest tree used in the four areas studied are shown in Table 11. There were no preferences for either living or dead trees and in all areas except for Tarwonga, the dominant woodland species provided the majority of nest sites. At Tarwonga, marri, though dominant, provided no suitable hollows as floors were level with the entrances. Only one marri hollow was found to be of suitable size and shape.

5.1.5 Characteristics of nest hollows.

5.1.5.1 Aspect of hollow. The aspect of a hollow is defined as the direction towards which the hollow opens (Figure 23a) and has also been described as the orientation of the hollow or nest cavity (Connor, 1975).

At Coomallo Creek and Manmanning, the aspects of the entrances of all hollows used by White-tailed Black Cockatoos any time during the study were recorded and placed into one of nine classes. These were the vertical aspect class (Figure 23b) and eight equal segments of the compass with the major points of the compass at their centre (i.e. N, NE, E, etc.).

TABLE 11

Number of each species with a suitable sized hollow tagged in area

Area	Wandoo	Powder-bark Wandoo	Salmon Gum	Gimlet	Marri	Swamp Yate	York Gum	Total
Coomallo Creek	175†	2	*	*	*	*	0	177
Manmanning	3	*	74†	1	*	*	*	78
Tarwonga	41	*	*	*	1†	*	*	42
Moornaming	2	*	39†	*	*	4	*	45

† Dominant species in area

* Does not occur in study area

Figure 23(a). Hollow in wandoo with horizontal aspect

Figure 23(b). Hollow in wandoo with vertical aspect

In the analysis of use, each hollow was scored once for each year that it was known to be available as a nest site. For example, if a hollow was found to be used in 1970 and was available each year until 1973 when it was no longer suitable for use, then it was scored three times.

The number of available hollows and the aspects of these hollows at Coomallo Creek and Manmanning from 1970 to 1974 is shown in Table 12. In both areas about 40 per cent of the available hollows had vertical aspects and the remainder opened in various directions which were not randomly distributed (χ^2 test) among the compass classes. At Coomallo Creek there were no hollows opening east and less than expected opening west and north-west. At Manmanning, there were less opening to the north-east and south and more opening to the east than expected.

In addition to the destructive agents attacking the tree from the inside, wind is probably the other main cause of branches breaking off in both study areas. Lightning strikes and bush fires also assist in this but are probably of minor importance compared to wind. The only records of wind velocity near the two areas are kept by the Bureau of Meterology for Jurien (approximately 40 km west of Coomallo Creek) and Wongan Hills (approximately 30 km west of Manmanning). These are taken at 0900 and 1500 hours daily and have only been taken for three years. No consistent relationship between orientation of broken branches and wind direction was apparent. For example, at Jurien the dominant wind direction was from the south to south-east. Those branches at right angles to the wind present the greatest resistance to the wind and more of these would be expected to be broken off than from other directions. This is true of branches out to the west at Coomallo Creek but there

TABLE 12

Number of hollows available and their aspects
at Coomallo Creek and Manmanning (1970-1974).

Aspect	COOMALLO CREEK		MANMANNING	
	Actual no. of hollows	Departure from random (N=31.875)*	Actual no. of hollows	Departure from random (N=13.625)*
North	23		16	
North-east	20	$0.05 > P > 0.02$	6	$0.05 > P > 0.02$
East	0	$0.001 > P$	22	$0.05 > P > 0.02$
South-east	31		19	
South	41		5	$0.02 > P > 0.01$
South-west	37		9	
West	56	$0.001 > P$	18	
North-west	47	$0.01 > P > 0.001$	14	
SUB-TOTAL	255		109	
Vertical aspect	174	% of total = 41%	64	% of total = 37%
TOTAL	429		173	

* Expected number in each aspect (excluding vertical aspect) assuming a random distribution.

were none off to the east which is equally at risk. This suggests a more complex relationship than that inferred from hollow orientation and prevailing wind.

Black cockatoos may only use those nest hollows that are available but given this selection they may have preferences for hollows with certain aspects. This has been found in woodpeckers and Reller (1972) found that most nest entrances of the Red-head, Melanerpes erythrocephalus, and Red-bellied, Centurus carolinus, Woodpeckers faced south-westerly. It was suggested that this orientation increased both ventilation by wind and warming by sun with the possibility that this eased the adults' incubation duties during cool weather. Bent (1939) (in Conner, 1975) stated that in the Pileated Woodpecker, Dryocopus pileatus, nest entrances usually faced east or south and suggested wood quality and slope of the trunk probably had an additional effect on orientation. Connor (1975) found that most woodpecker nests he examined opened downward and suggested that these hollows are less likely to fill with water and that the underside of a tree is easier to excavate because it is a moister micro-environment than the upperside. Woodpeckers excavate their own hollows whereas the White-tailed Black Cockatoos do not. The aspects of all hollows used by White-tailed Black Cockatoos at Coomallo Creek and Manmanning are shown in Table 13. In both areas there is no departure from a random selection of available hollows and so no bias towards any specific aspect. This was found in the Eastern Bluebird, Sialia sialia, which often nests in hollows produced by woodpeckers. Although the aspects of these hollows are not randomly distributed, the choice by bluebirds was thought to represent a random selection of available hollows (Pinkowski, 1976).

TABLE 13

Aspect of hollows used by White-tailed Black Cockatoos

	COOMALLO		MANMANNING	
Aspect	Actual hollows used	Expected*	Actual hollows used	Expected*
North	21	15.44	7	7.03
North-east	14	13.43	2	2.63
East	0	0	8	9.66
South-east	22	20.81	8	8.35
South	24	27.52	1	2.20
South-west	15	24.84	6	3.95
West	42	37.59	10	7.91
North-west	21	31.55	5	6.15
Vertical	129	116.82	29	28.12
TOTAL	288	288	76	76
	X^2_8 = 11.76 Not significant		X^2_8 = 3.09 Not significant	

* This value is: $\frac{\text{No. of hollows face this way}}{\text{Total no. available in area}} \times$ Total actually used

Although White-tailed Black Cockatoos showed no preference for any aspects when selecting a hollow there is the possibility that hollows facing in some directions may be less suitable for shelter. Those opening vertically or into the prevailing wind may be more exposed and, therefore, place the nestlings at more risk than in other hollows. This appears to be unlikely because if this was the case, random choosing of hollows could be selected against, or conversely, choice of more suitable aspects selected for. The random choice of hollows may be an outcome of their behavioural evolution, rather than an example of catholic taste. In order to examine this hypothesis, the hollows used at Coomallo Creek have been divided into successful (young fledged) and unsuccessful (nesting attempt failed) categories and these are shown in Table 14. Here again, in both categories, there was no departure from random and no specific aspect was more, or less, successful than any other. In addition, at Coomallo Creek the selection of hollows at different times of the breeding season also occurs on a random basis. This indicates that there is no advantage in being selective regarding choice of hollow based on aspect. The sample at Manmanning was too small for these types of comparisons to be made.

Some hollows are susceptible to flooding but in these cases it is usually as a result of stem run-off collecting in the hollow. These hollows are usually located in a fork or some other area prone to this type of water collection. Hollows which have entrances at the end of a spout away from the trunk of the tree do not seem to be as prone to flooding. In these cases the only water collecting inside is from rain blown or falling through the entrance. The porous nature

TABLE 14

Coomallo Creek : Aspect of hollows used successfully and unsuccessfully

Aspect	Successful hollows		Unsuccessful hollows	
	Actual hollows used	Expected	Actual hollows used	Expected
North	18	10.99	3	4.66
North-east	10	9.56	4	4.06
East	0	0	0	0
South-east	16	14.81	6	6.29
South	18	19.59	6	8.31
South-west	11	17.68	4	7.50
West	31	26.76	11	11.36
North-west	14	22.46	7	9.53
Vertical	87	83.15	46	35.29
TOTAL	205	205	87	87
	$X^2_8 = 11.28$ Not significant		$X^2_8 = 6.80$ Not significant	

of the floor usually allows this to drain away faster than it collects and the nestlings can usually manage to stay dry.

5.1.5.2 Depth of hollow. The depth of each hollow at Coomallo Creek and Manmanning was measured from the lowest point of the entrance to the floor and these measurements are given in Table 15. In both areas these have been subdivided into successful and unsuccessful categories and there was very little difference in the mean depth of successful or unsuccessful hollows in either area. Depth of hollow does not appear to be a contributing factor to nest failure. There was little difference between mean depth of hollows at either area.

In both areas the depth of each hollow when first measured was compared with its depth in 1975 and the change in depth noted. At Coomallo Creek hollow floor levels fell at an average rate of 3.2 cm per year. One hollow floor was raised 67 cm in 5 years; another did not change in 6 years; and a third fell 161 cm in 3 years. At Manmanning, floor levels dropped at an average rate of 4.3 cm per year. One floor was raised 46 cm in 5 years and at that stage the floor was level with the entrance; another dropped 1 cm over 4 years; and a third dropped 730 cm in one year - there was a hole in the tree at ground level and the decayed wood spilled out this hole and the tree became a hollow shell with an entrance on ground level.

Usually the level of hollow floors drop as a result of compression of the decayed heartwood material. Floor levels rise because material is added. This may come from the ceiling of the hollow or from the outside. Galahs, Cacatua roseicapilla, use compressed sprays of

TABLE 15

Depth of hollow floor from entrance

Depth (metres)	COOMALLO CREEK Successful hollows	COOMALLO CREEK Unsuccessful hollows	COOMALLO CREEK Total	MANMANNING Successful hollows	MANMANNING Unsuccessful hollows	MANMANNING Total
0.0 - 0.1			0			0
0.1 - 0.5	19 (9%)	15 (17%)	34 (12%)	1 (4%)		1 (1%)
0.5 - 1.0	80 (39%)	35 (40%)	115 (39%)	9 (32%)	22 (44%)	31 (40%)
1.0 - 1.5	63 (31%)	25 (29%)	88 (30%)	5 (18%)	16 (32%)	21 (27%)
1.5 - 2.0	35 (17%)	9 (10%)	44 (15%)	9 (32%)	8 (16%)	17 (22%)
2.0 - 2.5	8 (4%)	3 (4%)	11 (4%)	2 (7%)	1 (2%)	3 (4%)
2.5 +			0	2 (7%)	3 (6%)	5 (6%)
Total No.	205	87	292	28	50	78
Mean Depth	1.06	0.96	1.03	1.33	1.22	1.26

green leaves as a nest lining (Forshaw, 1969) and this may raise the nest floor, as do Barn Owl, Tyto alba, pellets and bird excreta.

There were two cases in which the floor level fell while it was actually being used by White-tailed Black Cockatoos. Neither of these nests failed as a result of this. There were three cases in which parts of the ceiling of the hollow fell in while the hollow was in use. One of these nesting attempts failed because a large piece of wood blocked the spout and the adults were not able to get near enough to the nestling to feed it and the nestling starved. The adults did try to chew through the blockage but it was too substantial. In another of these cases, the ceiling of one hollow formed part of the floor of a hollow situated higher in the tree. The lower hollow was occupied by a large White-tailed Black Cockatoo nestling and the higher one by a large Long-billed Corella, Cacatua tenuirostris, nestling. The collapse of the floor of the higher hollow resulted in one single deep hollow with two separate entrances and two nestlings side by side on the floor. Both nestlings fledged successfully.

5.1.5.3 Height to entrance of hollow. The height to the entrance from ground level at both Coomallo Creek and Manmanning was measured and these measurements are given in Table 16. In both areas these have been subdivided into successful and unsuccessful categories. There was little difference between the mean heights for either category at Coomallo Creek or Manmanning. It appears that nest entrance height does not affect nesting success. Mean nest entrance height at Manmanning is nearly two metres higher than at Coomallo Creek but this is because the salmon gums at Manmanning are taller trees with a shape different from that of the Wandoo which predominate at Coomallo Creek.

TABLE 16

Height of nest entrance from ground

Height (metres)	COOMALLO CREEK Successful hollows	COOMALLO CREEK Unsuccessful hollows	COOMALLO CREEK Total	MANMANNING Successful hollows	MANMANNING Unsuccessful hollows	MANMANNING Total
0 - 2			0			0
2 - 3	8 (4%)	5 (6%)	13 (5%)			
3 - 4	25 (12%)	11 (13%)	36 (13%)		1 (2%)	1 (1%)
4 - 5	61 (30%)	20 (24%)	81 (28%)	1 (4%)	2 (4%)	3 (4%)
5 - 6	35 (17%)	18 (22%)	53 (19%)	2 (8%)	4 (8%)	6 (8%)
6 - 7	39 (19%)	12 (15%)	51 (18%)	2 (8%)	12 (25%)	14 (19%)
7 - 8	30 (15%)	16 (20%)	46 (16%)	15 (58%)	21 (44%)	36 (49%)
8 - 9	3 (2%)		3 (1%)	3 (11%)	5 (11%)	8 (11%)
9 - 10	1 (<1%)		1 (<1%)		2 (4%)	2 (3%)
10 +			0	3 (11%)	1 (2%)	4 (5%)
Total No.	202	82	284	26	48	74
Mean height	5.43	5.24	5.38	7.38	7.00	7.13

There is no evidence to indicate that the birds always choose hollows that are high up as has been noted by Serventy and Whittell (1976). The birds may only nest in hollows that are available and if these happen to be only two metres off the ground, they are used.

5.1.6 Loss of hollows. By the end of 1971 there were 46 suitable hollows recorded at Manmanning and by the end of 1976 there were 35 of these still suitable for nesting (loss of 4.8% of hollows per year). At Coomallo Creek, by the end of 1972 there were 110 hollows marked and 98 left at the end of 1977 (loss of 2.2% of hollows per year). These losses were caused by trees being blown over, bulldozed in clearing operations, burnt, sections being broken off, the floor falling so far that it became too narrow for use, or the ceiling falling in and filling the hollow.

Many of the mature and over-mature trees that have hollows in them are particularly susceptible to fire. This is especially true of Wandoo and Salmon Gum. In some cases the tree may have only a hollow shell of living material around the trunk with rotten heartwood. A fire moving through the area and starting to burn at the base of this type of tree soon eats through the base shell and quickly becomes a tunnel of fire which destroys the tree. This was seen at Tarwonga after the Forests Department had put in a slow reduction burn. A number of hollow trees were destroyed during this burn. At Coomallo Creek during the first half of 1977, a fire burnt through part of the study area and six hollow trees were completely destroyed.

There are few data on the rate of creation of hollows over the period of the study. The trees were marked in the early part of the study because they were of a suitable size for use by White-tailed Black Cockatoos and subsequently trees were added to the record once they had been used by the birds. There was no way of knowing how long the hollows had been available to the birds before the hollows were marked.

The only information on hollow creation was gained at Coomallo Creek. A branch fell off a tree after a storm, exposing a large cavity which had been hitherto inaccessible and it was used within three weeks of its creation.

5.1.7 Use of hollows by other species. The use of nest hollows by other species varied from year to year. Wood Duck, Chenonetta jubata, at Coomallo Creek and Mountain Duck, Tadorna tadornoides, at Manmanning, contributed most to this variation. Both species leave the hollow vacant after they have incubated their young and because they usually complete their nesting before the start of the White-tailed Black Cockatoo breeding season, use of nest hollows by ducks does not prevent their use by White-tailed Black Cockatoos subsequently in the same year.

Species which used hollows at the time of the White-tailed Black Cockatoo breeding season were the the Galah, Long-billed Corella, Port Lincoln Parrot, Barnardius zonarius, Smoker Parrot, Polytelis anthopeplus, Nankeen Kestrel, Falco cenchroides, Barn Owl, Boobook Owl, Ninox novaeseelandiae and feral bees, Apis sp. Bees have become a problem at Coomallo Creek and in one season (1975), two nests failed (one on eggs, one on nestling) because bees swarmed into the hollows and established hives there.

In any year at either area there was never more than 53 per cent occupancy of available hollows by all species excluding the ducks. The range at Coomallo Creek between 1972 and 1976 was 38 to 53 per cent and at Manmanning, from 1971 to 1976, it was 29 to 53 per cent. The annual average occupancy at Coomallo Creek during the study was 45 per cent and at Manmanning, 41 per cent.

Galahs were the most important of the species that used hollows of a size suitable for White-tailed Black Cockatoos, but they appeared to prefer hollows with smaller entrances than those normally used by black cockatoos. As a result, there was not a great overlap in hollow usage between the two species.

5.1.8 Nest hollow spacing. In one discrete patch of woodland there were eleven hollows that had been used by cockatoos some time in the previous seasons. In order to see if the provision of more hollows would lead to increased usage of the area an extra eleven hollows were created. This was done by cutting doors into the sides of trees that appeared to have suitably sized entrances but were blocked with decayed heartwood. This decayed matter was removed via the access door and a hollow created. The access door was then blocked up. Four of these hollows were subsequently used: two by White-tailed Black Cockatoos, and two by other species. There was no increase in the number of Black Cockatoo nests in the area in the four breeding seasons following. It would appear that the birds do not nest in groups but may space themselves out through the available area. The provision of more hollows, not leading to more nests in the area seems to indicate that some other factor was involved.

The distribution of nest hollows used in 1975 is shown for Coomallo Creek on Figure 24 and Manmanning on Figure 25. In order to see if there was any evidence of spacing out of White-tailed Black Cockatoos nests in the available area, the distance between nest trees and the nearest available nest tree to it was calculated using an aerial photograph of the area with the nest trees plotted on it. The results of these calculations for Coomallo Creek each year from 1974 to 1976 are shown on Table 17. There were 143 trees with hollows available during this period and the mean distance between each nest tree and its nearest neighbour was 100 metres. For each breeding season from 1974 to 1976 the distance between each nest tree used in that season and its nearest used neighbour was calculated from the aerial photograph. The mean distance between nest trees that were actually used and their nearest neighbour was 174 metres for the three seasons.

A further breakdown was done and the distance between a hollow that was laid in during a particular week and any others also laid in during that period together with hollows that were first used the previous week was calculated. This was done for each week of the laying season. The reasoning behind this calculation and the overlap of periods was that a female prospecting for a nest hollow may be influenced by another female who is also prospecting or preparing a hollow (see section 9.7.2.1). Once a female is incubating she remains in the hollow continuously except for 20 to 30 minutes each day and during this period she is with the male being fed. At this stage she is unlikely to affect any other birds prospecting for hollows. The results of these calculations for the three seasons gave a mean distance between hollows

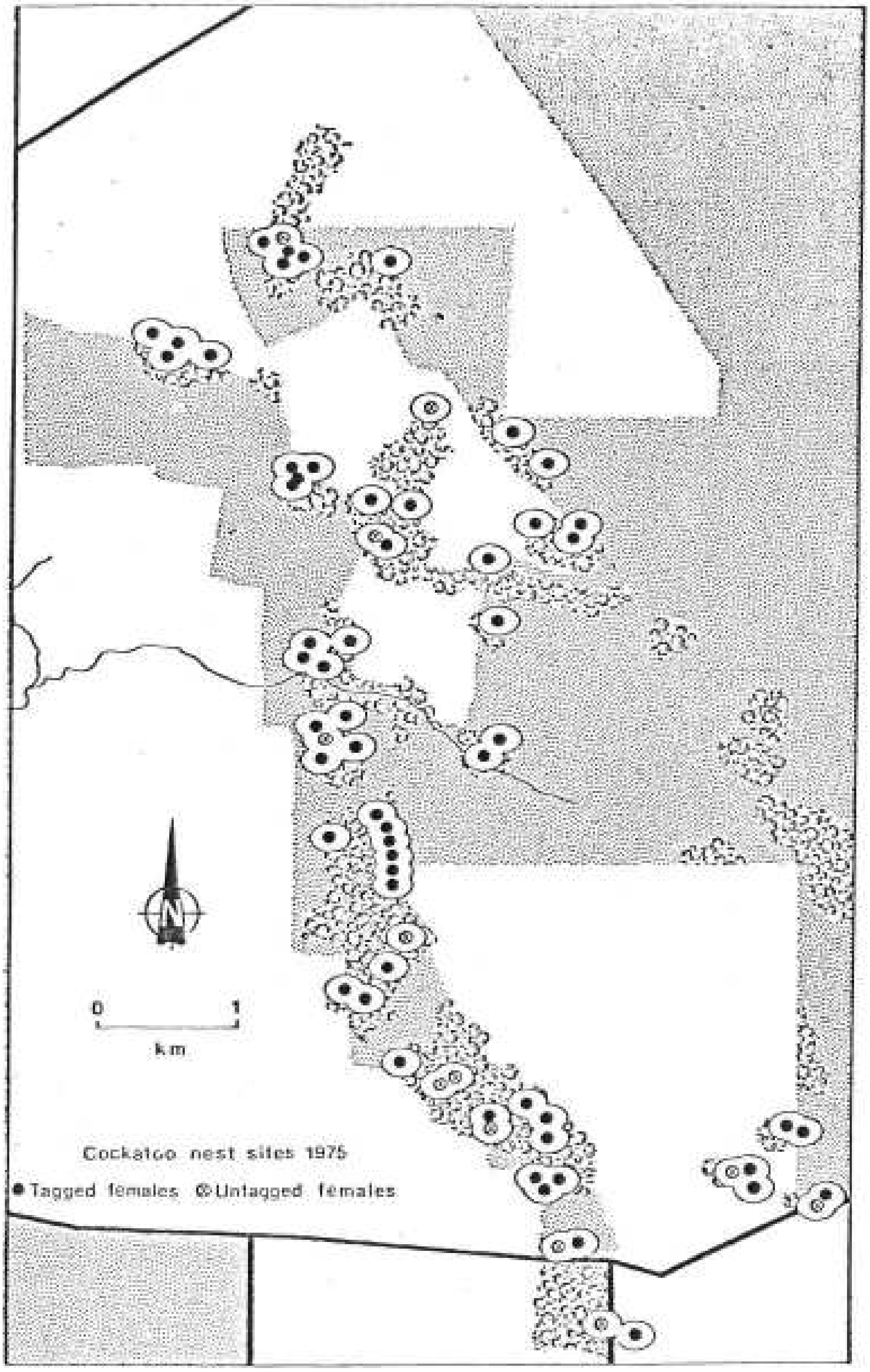

Figure 24. Coomallo Creek. Locations of nest hollows used in 1975. Each dot represents one tree.

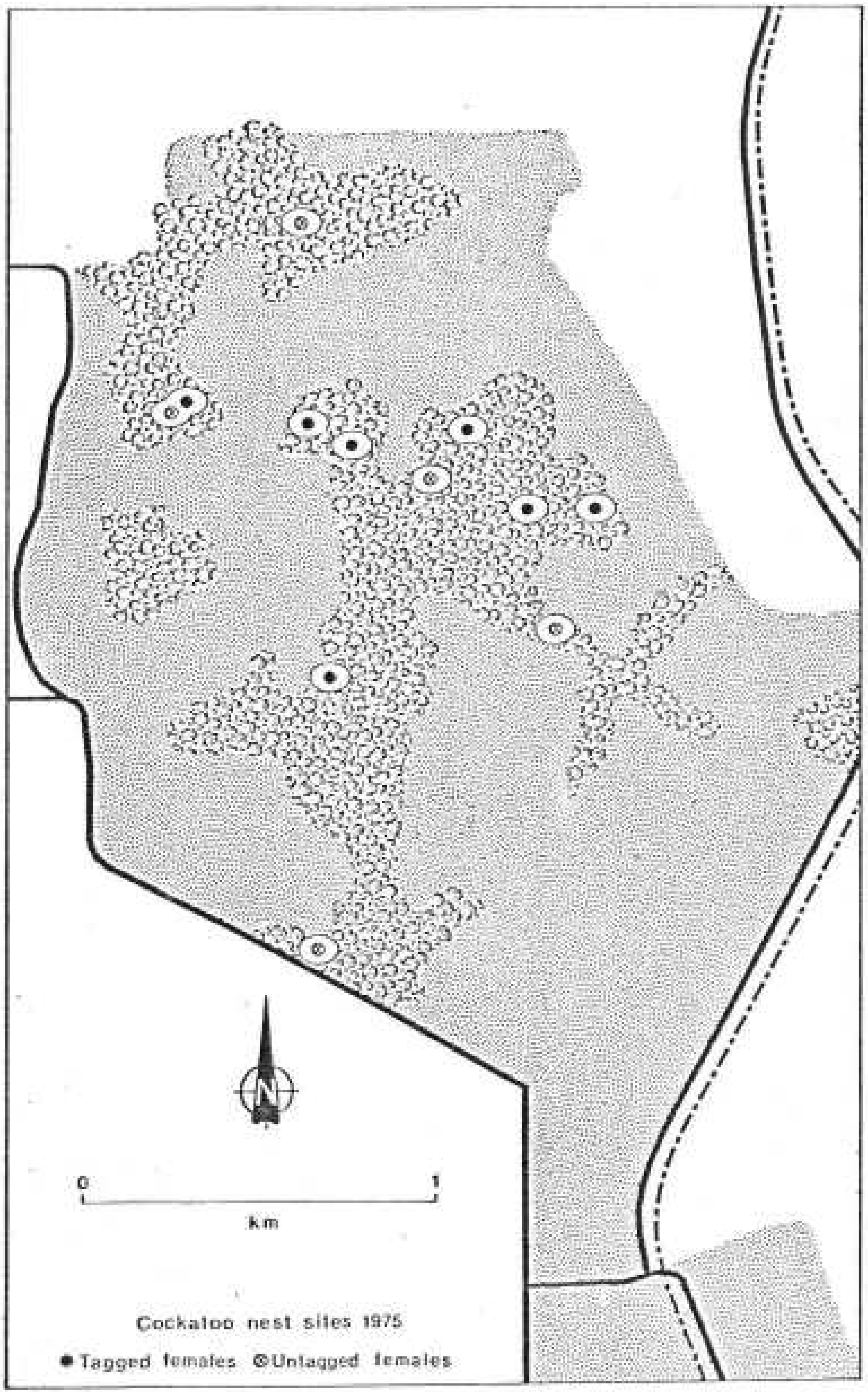

Figure 25. Manmanning. Location of nest hollows used in 1975.

TABLE 17

Closest nest hollow analyses (± standard error)

	1974	1975	1976	Mean distance for 3 years
Mean distance (metres) between closest hollow trees over study area (N = 143)	100±7	100±7	100±7	100±7
Mean distance (metres) between closest hollow trees used in season (No.)	173±17 (68)	145±17 (70)	214±33 (55)	174±13(a)
Mean distance (metres) between closest hollow trees used in a particular week or the previous week.	738±85	854±88	802±106	800±53(b)

Significant difference between mean values (a) and (b), d = 11.4 (.001 > p) of 800 metres. A d-test was carried out to compare the mean distance between nearest neighbours over the entire season with the mean distance between nearest neighbours commenced in a particular time. There was a significant difference between the means; d = 11.4 with 206 degrees of freedom 0.001 > P.

5.2 Laying seasons.

The laying season is taken as the period over which eggs are laid. The laying date for the first egg from each nest is used in all calculations and these dates are grouped into weeks, week one being 1-7 July.

5.2.1 Laying seasons for study areas.

The laying dates for the first egg in each nest at Coomallo Creek and Manmanning for each year from 1970 to 1976 are shown in Figures 26 and 27. These are subdivided to show the number of eggs that successfully gave rise to young that left the nest and those that did not.

At both Coomallo Creek and Manmanning the laying seasons were regular. At Coomallo Creek the average start of laying was during week four and varied two weeks either side of that (Figure 26). Manmanning laying started on average during week eight and varied two weeks either side (Figure 27).

The laying seasons appear to be regular both in start and finish and there was no apparent trend due to any one climatic influence.

5.2.2 Laying seasons of individual females.

The laying dates of the first egg for individual females in relation to the start of laying each season for 12 Coomallo Creek females and 10 Manmanning females were examined. None of the females in either area appeared to

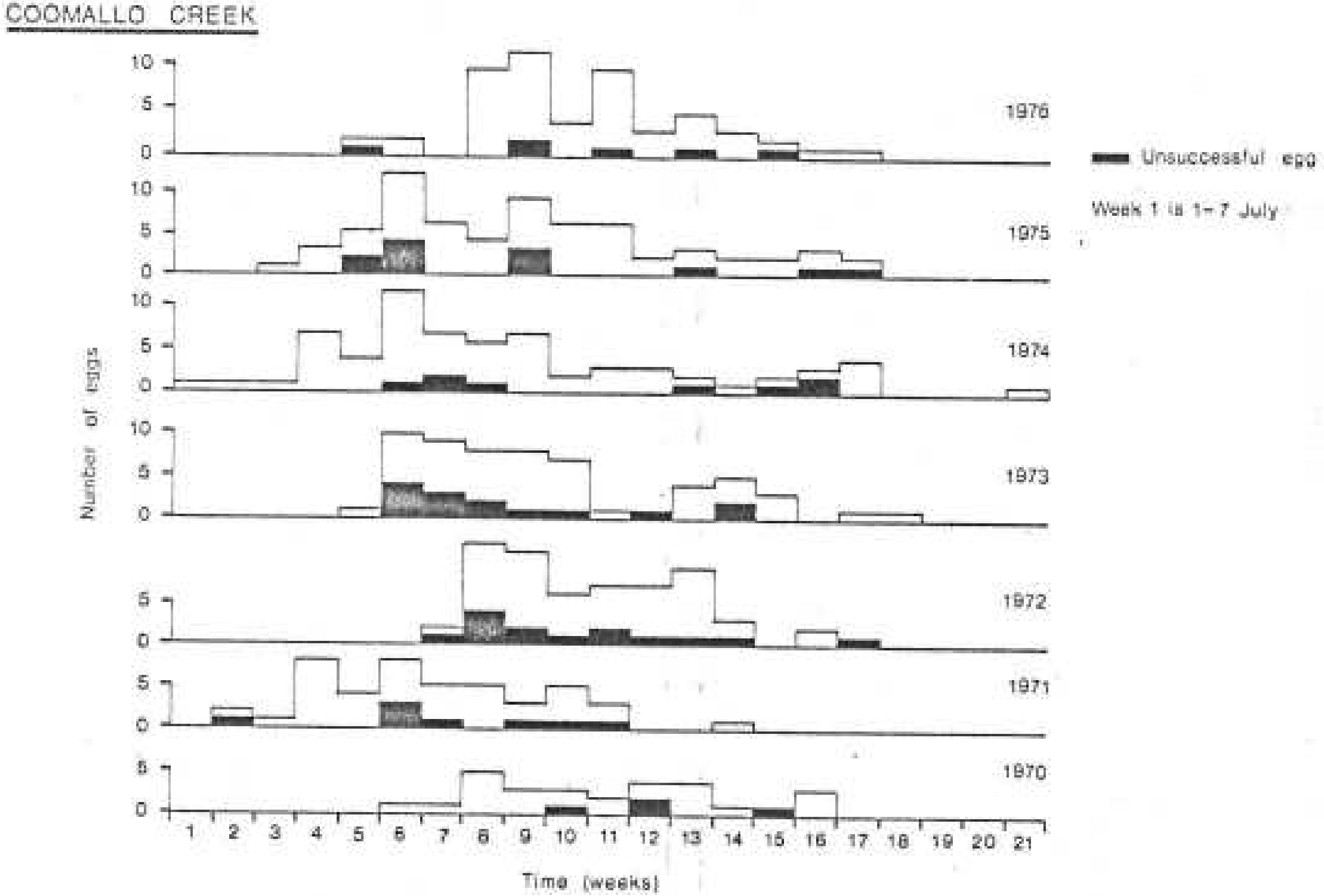

Figure 26. Laying dates for first egg in each nest at Coomallo Creek.

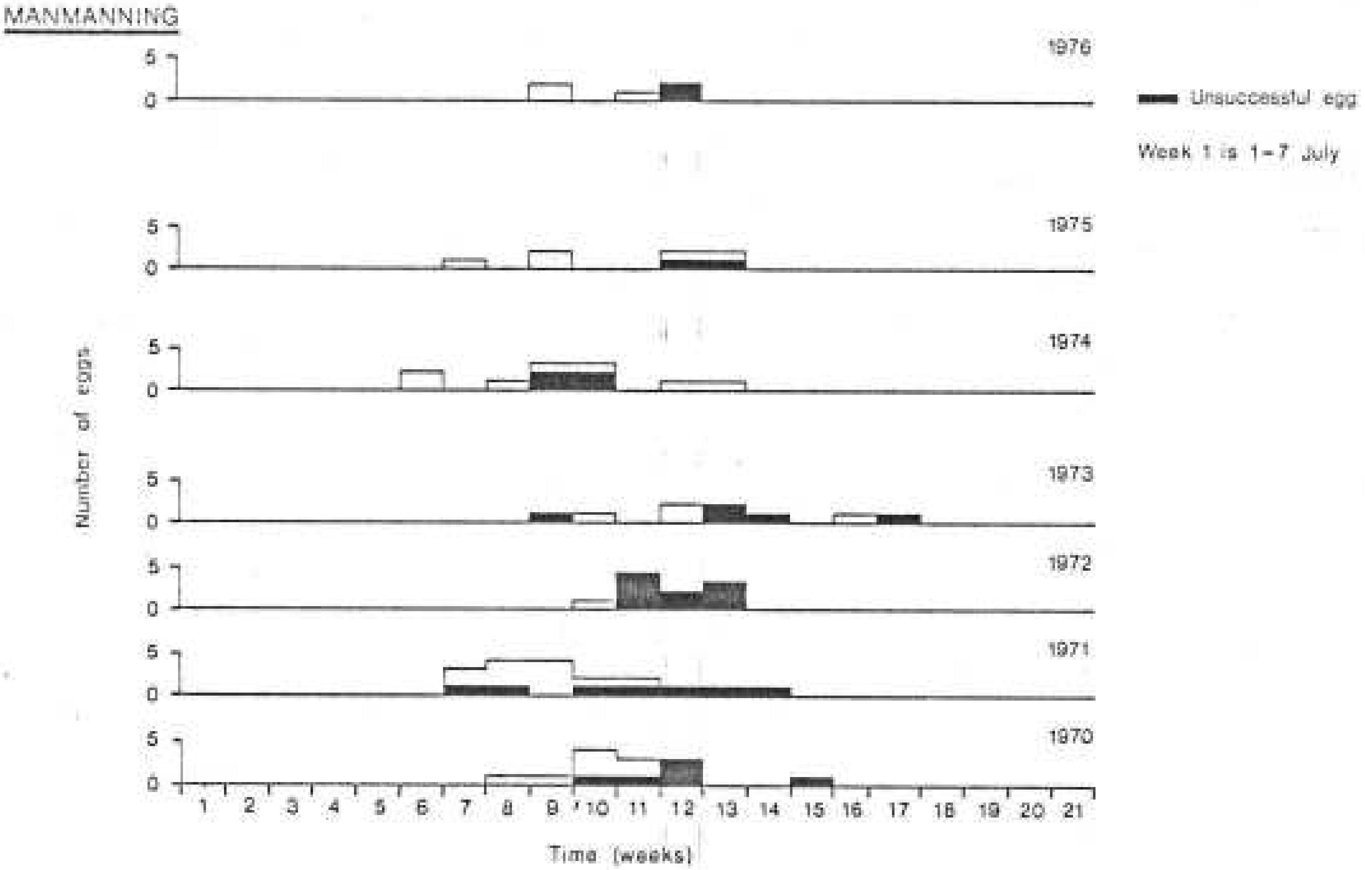

Figure 27. Laying dates for first egg in each nest at Manmanning.

be consistent over the different years in the time she layed after the start of the season or in order of laying as far as other females were concerned.

5.3 Weights of breeding adults. During 1970 and 1971 the weights of all the breeding adults handled at Coomallo Creek and Manmanning were noted. The mean adult weights and ranges for 22 females and eight males at Coomallo Creek, and 15 females and 10 males at Manmanning are shown on Table 18. Also on this table are the mean adult weights of a sample collected throughout the range of the White-tailed Black Cockatoo (Saunders 1974c) and these are given as a population estimate.

The weights of males from Coomallo Creek and both sexes from Manmanning did not differ from the population sample but females from Coomallo Creek were significantly heavier than the population estimate. (Table 18).

The sample of birds used in the population estimate (96 females; 90 males) was collected during the period January through to August in areas where groups of birds congregate outside the breeding season. It is probable that females increase in weight prior to breeding. The Coomallo Creek sample indicates that females are heavier than average in the early part of the breeding attempt but the Manmanning females have remained the same weight into the breeding season.

5.4 Eggs.

5.4.1 Description. White-tailed Black Cockatoo eggs are creamy-white and oval with one end slightly more pointed than the other (Figure 28).

TABLE 18

Weights of breeding adults (1970/71)

	Coomallo Creek		Manmanning		Population sample various areas*	
	Mean wt. (range)	No.	Mean wt. (range)	No.	Mean wt. (range)	No.
Females	698 (590-770)	22	669 (590-780)	15	668 (560-790)	96
Males	649 (610-700)	8	644 (600-700)	10	653 (540-760)	90

* Data from Saunders (1974*c*)

Coomallo Creek ♀♀ significantly heavier than population sample $0.01 > P > 0.001$

No difference in ♂♂ samples

Figure 28. Clutch of two eggs on floor lined with wood chips

5.4.2 Clutch size. From observations made on 526 clutches, the maximum number of eggs in a clutch is two.

The clutch sizes for Coomallo Creek and Manmanning from 1970 to 1976 are shown in Table 19. There were no significant differences between years at Manmanning but there were significant differences between years at Coomallo Creek where there were more two-egg clutches in 1970 than 1973 which had the least.

Over all years there were significant differences between Coomallo and Manmanning with Coomallo having more two-egg clutches.

The clutch sizes for Tarwonga and Moornaming for 1970 are shown in Table 20.

5.4.3 Measurements. The mean lengths, widths and ranges of measurements for eggs of single and two-egg clutches are shown in Table 21. An analysis of variance was carried out to determine any difference between egg lengths and widths from the different study areas. There was no significant difference in widths of eggs from any category or between lengths of eggs from different areas in the same categories. There was no significant difference in lengths between the larger eggs of two-egg clutches and the eggs of single egg clutches, yet these two categories were significantly longer than the smaller eggs of two-egg clutches (t-test; $0.001 > P$).

5.4.4 Eggshell thickness. Seven or eight freshly hatched eggs from each area were measured to see if there were any differences in thickness of the shell between areas. Each egg was measured in ten different places. There were no significant differences in eggshell

TABLE 19

Clutch size : Coomallo Creek and Manmanning

	1970	1971	1972	1973	1974	1975	1976	Total
MANMANNING:								
No. nests with one egg	5	4	6	7	4	4	1	31
No. nests with two eggs	10	17	8	9	8	8	3	63
Clutch size	1.67	1.81	1.57	1.56	1.67	1.67	1.75	1.67
COOMALLO CREEK:								
No. nests with one egg	2	14	10	22	15	14	11	88
No. nests with two eggs	17	43	39	35	47	73	58	312
Clutch size	1.90	1.75	1.80	1.62	1.76	1.84	1.84	1.78

Comparison between years in clutch size: Manmanning $X^2_6 = 3.42$ $0.70 > P > 0.50$ Not significant
Coomallo Creek $X^2_6 = 14.32$ $0.05 > P > 0.02$ Significant

Comparison between areas (1970-1976) $X^2_1 = 5.02$ $0.05 > P > 0.02$ Significant difference between areas

TABLE 20

Clutch size : Tarwonga and Moornaming (1970)

	Tarwonga	Moornaming
No. nests with one egg	3	8
No. nests with two eggs	12	9
Clutch size	1.80	1.59

TABLE 21

Egg measurements

	Length (mm) [Range]	Standard Deviation	Width (mm) [Range]	Standard Deviation	No. in sample (all areas combined)
SINGLE-EGG CLUTCHES					
	48.8	2.2	34.7	1.4	35
	[43.8 - 52.2]		[31.9 - 37.6]		
TWO-EGG CLUTCHES					
			LARGER EGG		
	48.5	2.5	34.7	1.6	41
	[44.8 - 54.1]		[31.5 - 40.9]		
			SMALLER EGG		
	45.7	2.2	34.1	0.8	41
	[39.8 - 50.5]		[31.8 - 39.5]		

thickness between areas and the mean eggshell thickness for the 29 eggs was 0.38 mm.

5.4.5 Pesticide levels. Thirteen fully incubated eggs were examined by the Western Australian Government Chemical Laboratories for the presence of BHC and DDT or its metabolites. All eggs had only negligible amounts of pesticide present in them (Table 22).

5.4.6 Interval between laying of first and second egg. The intervals between the laying of the first and second egg in two-egg clutches are known for 60 clutches. The mean interval is eight days and the second egg may be laid any time from one to 16 days after the first.

Normally the second nestling dies within 48 hours of hatching but in eight out of 526 nests observed (i.e. 1.5%) both nestlings were raised and subsequently fledged. The intervals between the eggs in these eight cases ranged from 1 to 12 days.

5.4.7 Incubation. The female sits continuously after the laying of the first egg. During this period, and for an unknown period after, she has a patch on her abdomen which is devoid of feathers. The females do all the incubating and a male has never been seen entering or leaving a nest hollow while its mate was incubating.

The incubation periods were accurately recorded for four nests and there were two instances of 28 days and two of 29 days. Because nests were not visited every day, the incubation periods have been calculated on the maximum and minimum possible incubation time for each of 57 nests and these times are shown in Figure 29 and support the definition of the incubation period as 28-29 days.

TABLE 22

Pesticide levels in eggs (parts/million)

	BHC (Lindane)	DDT and Metabolites
Coomallo Creek	0.002	0.016
(10 eggs)	(0.000 - 0.003)	(0.004 - 0.040)
Manmanning	0.001	0.020
(3 eggs)	(0.001 - 0.002)	(0.020)

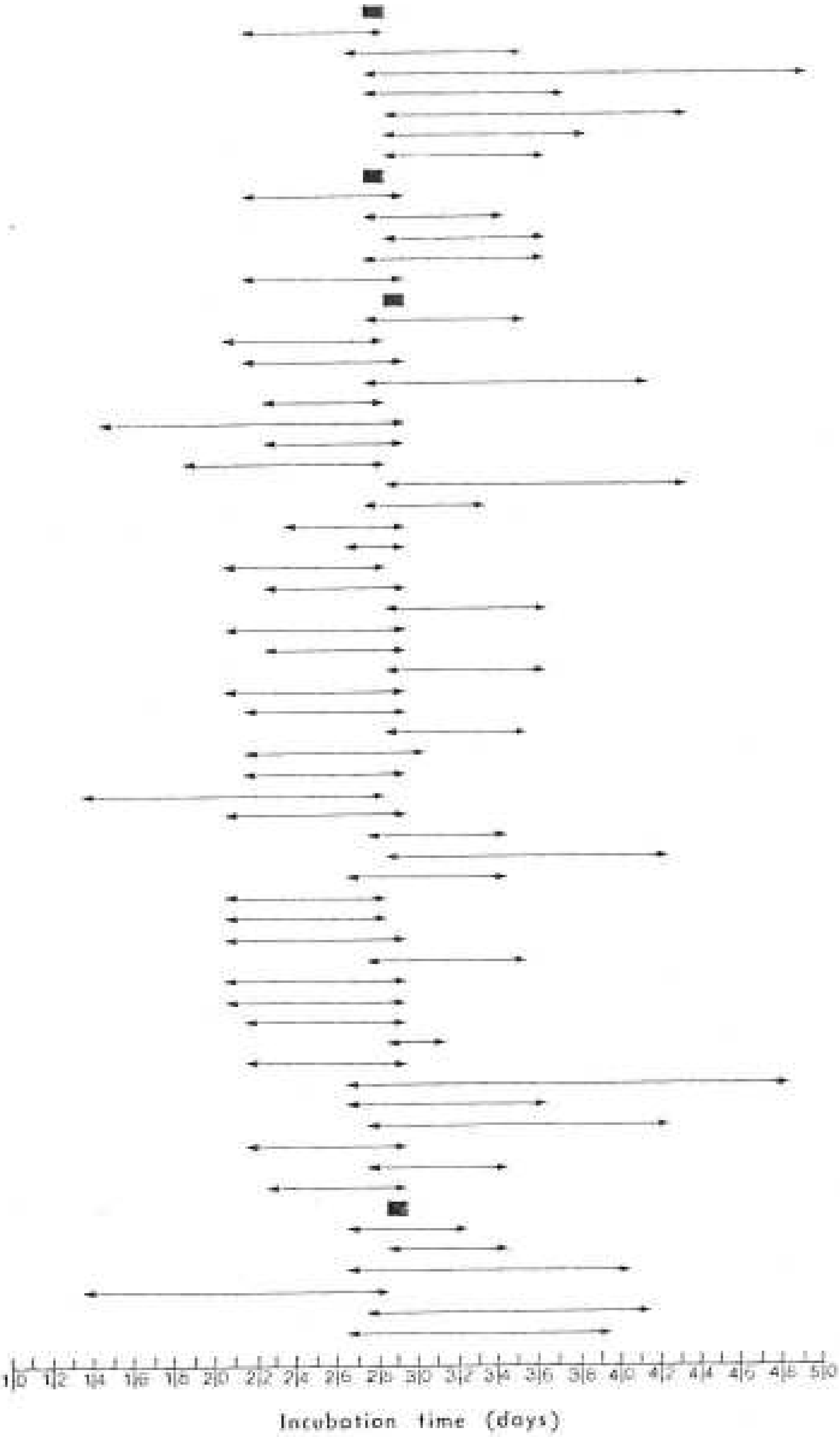

Figure 29. Maximum and minimum incubation times based on nest visits.

The fact that incubation is carried out constantly by one individual with about 30 to 40 minutes per day off the nest while she is fed, would account for the regular incubation period.

Limited data available on incubation times for the second egg indicate that it is the same period as the first. Once the first egg has hatched, the female continues to incubate the second egg and to brood the young nestling for at least 14 days. During this period her daily routine is the same as it was during incubation as she is still dependent on the male for food.

5.4.8 Hatching success. The hatching success (number of nesting attempts where eggs hatched) for both one and two-egg clutches for the years 1970 to 1976 is shown for Coomallo Creek and Manmanning in Table 23. There were no significant differences in hatching success between the years at either area and over all the years there were no differences between the two areas.

Overall in both areas, in 71 per cent of two-egg clutches both eggs hatched, whereas only 56 per cent of one-egg clutches hatched. The comparisons between hatching success of one-egg and two-egg clutches are shown in Table 24. In both areas there were significant differences between one-egg and two-egg clutches with two-egg clutches being more successful.

5.4.9 Fledging success. The fledging success (number of young fledged from nests where eggs hatched) for the years 1970 to 1976 is shown for Coomallo Creek and Manmanning in Table 25. There were no significant differences between years at either area for one-egg clutches and for two-egg clutches there were no significant differences between years at Manmanning but there were significant differences between years at Coomallo Creek.

TABLE 23

Hatching success : Coomallo Creek and Manmanning

	MANMANNING							COOMALLO CREEK						
	One-egg clutches			Two-egg clutches				One-egg clutches			Two-egg clutches			
	Failed	Hatched	Total	Both failed	Hatch 1 egg	Hatch 2 eggs	Total	Failed	Hatched	Total	Both failed	Hatch 1 egg	Hatch 2 eggs	Total
1970	3	2	5	2	0	8	10	0	2	2	1	3	13	17
1971	3	1	4	2	5	10	17	8	6	14	5	6	32	43
1972	3	3	6	1	1	6	8	3	7	10	6	12	21	39
1973	4	3	7	3	0	6	9	8	14	22	9	6	20	35
1974	2	2	4	0	0	8	8	6	9	15	3	8	36	47
1975	2	2	4	2	0	6	8	4	10	14	13	8	52	73
1976	1	0	1	0	2	1	3	5	6	11	6	4	48	58
TOTALS:	18	13	31	10	8	45	63	34	54	88	43	47	222	312

One-egg clutches: Comparison between years in hatching success: Manmanning $X^2_6 = 1.58$ N.S.
Coomallo Creek $X^2_6 = 4.47$ N.S.

Comparison between areas (1970-1976) $X^2_1 = 3.52$ N.S.

Two-egg clutches: Comparison between years in hatching success: Manmanning $X^2_6 = 5.04$ N.S.
Coomallo Creek $X^2_6 = 9.08$ N.S.

Comparison between areas (1970-1976) $X^2_1 = 0.19$ N.S.

TABLE 24

Comparison between hatching success of one-egg and two-egg clutches

	One-egg clutch	Two-egg clutch	Total
MANMANNING (1970-1976)			
Clutch failed to hatch	18	10	28
One or more eggs hatched	13	53	66
TOTAL	31	63	94
COOMALLO CREEK (1970-1976)			
Clutch failed to hatch	34	43	77
One or more eggs hatched	54	269	323
TOTAL	88	312	400

Manmanning: $X^2_1 = 17.68$ $0.001 > P$ Significant difference in hatching success

Coomallo Creek: $X^2_1 = 27.28$ $0.001 > P$ Significant difference in hatching success

TABLE 25

Fledging success : Coomallo Creek and Manmanning

	MANMANNING						COOMALLO CREEK					
	One-egg clutches			Two-egg clutches			One-egg clutches			Two-egg clutches		
	No. failed	% success	Total	No. failed	% success	Total	No. failed	% success	Total	No. failed	% success	Total
1970	5	0	5	4	60	10	1	50	2	3	82	17
1971	4	0	4	8	53	17	9	36	14	14	67	43
1972	5	17	6	8	0	8	4	60	10	17	56	39
1973	6	29	7	7	22	9	11	50	22	19	46	35
1974	3	25	4	4	50	8	8	47	15	9	81	47
1975	3	25	4	4	50	8	5	64	14	30	59	73
1976	1	0	1	1	67	3	6	45	11	14	76	58
TOTALS	26	16	31	36	43	63	44	50	88	106	66	312

One-egg clutches: No significant difference between years within areas.
Comparison between areas (1970-1976) $X^2_1 = 10.86$ $0.001 > P$

Two-egg clutches: Significant difference between years only at Coomallo Creek $X^2_6 = 18.86$ $0.01 > P > 0.001$
Comparison between areas (1970-1976) $X^2_1 = 11.96$ $0.001 > P$

There was a significant difference in fledging success for both one and two-egg clutches over all years between Manmanning and Coomallo Creek.

The comparisons between breeding success (number of nesting attempts that fledged young) of one-egg and two-egg clutches are shown in Table 26. In both areas eggs in two-egg clutches were more successful than those in one-egg clutches. These data were analysed further to examine the fledging success of those clutches which hatched at least one egg. Within each area there were no significant differences in fledging success between eggs of one-egg and two-egg clutches (those that hatched at least one egg). There were, however, significant differences between areas.

Within the study areas the difference in breeding success between one-egg and two-egg clutches is due to the difference in hatching success and not to any differences arising between hatching and fledging. Between the two study areas, however, the difference in breeding success of both sized clutches was due to events occurring between hatching and fledging, with birds at Manmanning being at some disadvantage compared with birds from Coomallo Creek.

As a result of two-egg clutches having a higher breeding success than one-egg clutches, there is a tendency for an increase in clutch size to be accompanied by an increase in nesting success expressed as a percentage of total nests in the area that fledged young. This relationship is shown in Figure 30 and this also shows that birds at Manmanning are at a disadvantage compared with those at Coomallo Creek. Those years at Manmanning with highest breeding success do not equal the

TABLE 26

Comparison between breeding success of one-egg and two-egg clutches (1970-1976)

	Total No. of clutches laid	No. of clutches that hatched at least one egg	% hatching success	No. of fledglings	% breeding success	% of hatched clutches that fledged young
MANMANNING						
One-egg clutches	31	13	42	5	16	38
Two-egg clutches	63	53	84	27	43	51
Total	94	66	70	32	34	48
COOMALLO CREEK						
One-egg clutches	88	54	61	44	50	81
Two-egg clutches	312	269	86	206	66	77
Total	400	323	81	250	63	77

1. In both areas there were significant differences in breeding success between one and two-egg clutches with two-egg clutches being more successful.
   Manmanning $X^2_1 = 6.61 \quad 0.01 > P > 0.001$
   Coomallo Creek $X^2_1 = 7.52 \quad 0.01 > P > 0.001$

2. There were no significant differences between one-egg and two-egg clutches in either area in the fledging success of clutches that hatched at least one egg. Therefore the difference in breeding success is due to the differences in hatching success.

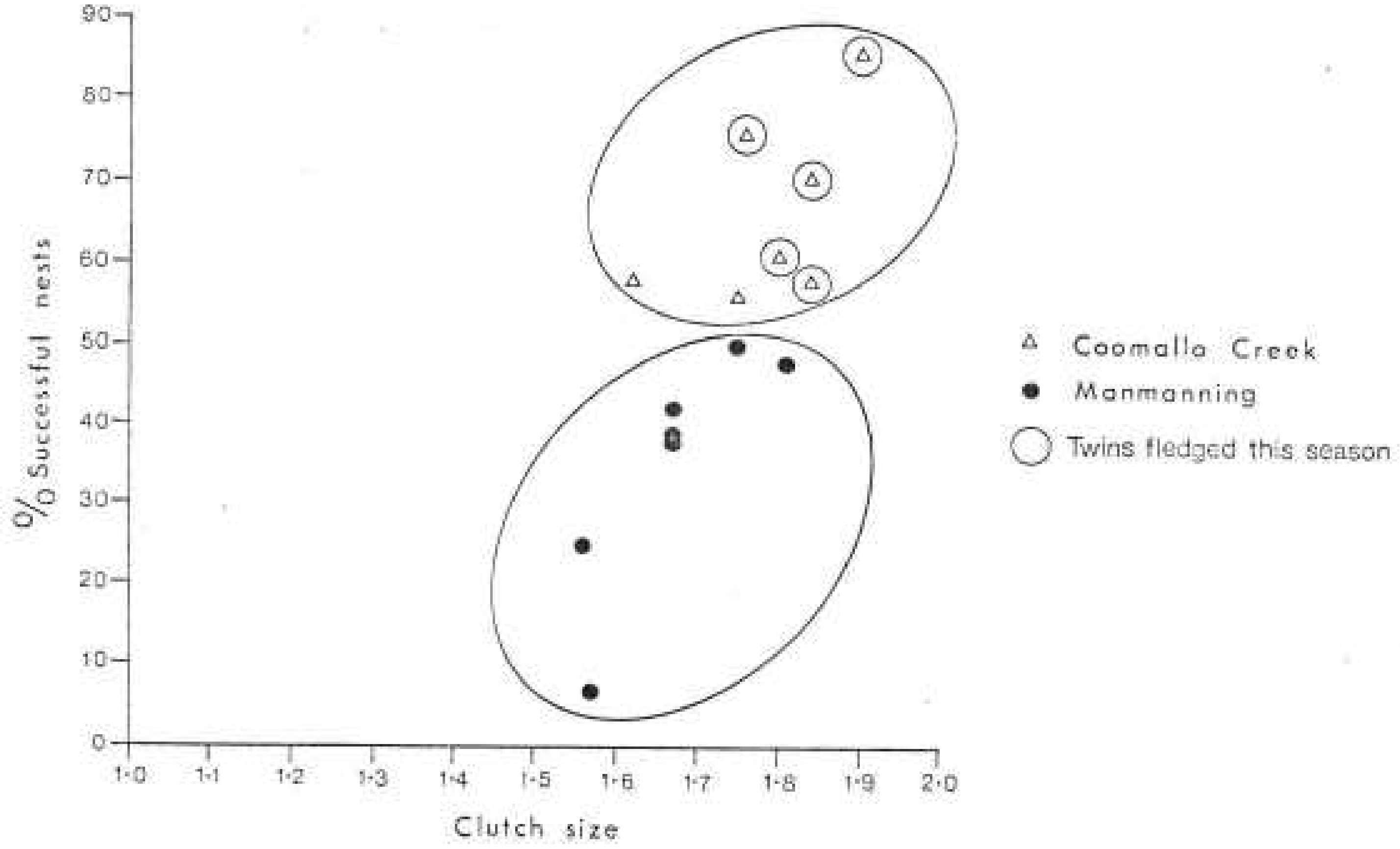

Figure 30. Clutch size plotted against % of successful nests each year (1970-1976) for Coomallo Creek and Manmanning.

worst years at Coomallo Creek. In 1970, 47 per cent of nests at Tarwonga fledged young, while 61 per cent did so at Moornaming.

5.4.10 Egg failures. Eggs fail for several reasons but these can be divided into two main categories: defects within the egg, or as a result of accidental loss.

5.4.10.1 Possible defects within the egg. No eggs were examined to check failures as a result of this so there are no data available. In two-egg clutches where one of the eggs failed to hatch, it was sometimes pushed over to one side of the nest, trampled into the nest floor or broken.

5.4.10.2 Accidental loss of eggs.

(i) Desertion. Females will readily desert if handled or frightened during incubation. The female is dependent on the male for food during this time and if he dies or disappears she will desert. During incubation at Coomallo Creek the females were always in the nest hollow or in the very near vicinity. At Manmanning incubating females were seen out foraging by themselves or with their mates. Two incubating females were taken by Wedge-tailed Eagles (*Aquila audax*) while out foraging, and such foraging leaves the eggs unguarded against predators or other hole-nesting birds.

(ii) Other hole-nesters. There is some inter-species aggression associated with the selection and preparation of a nest hollow and some instances of egg failure are attributable to the activities of other hole-nesters. The Galah maintains interest in its nest hollow throughout the year (Rowley, pers. comm.) whereas the White-tailed

Black Cockatoo is interested only during the breeding season. Hollows which have been Galah nests in previous seasons may be used by a White-tailed Black Cockatoo. In some cases the White-tailed Black Cockatoo chewed up the leaf lining prepared by the Galah prior to laying her clutch. In at least two of these cases, the White-tailed Black Cockatoo eggs were broken and the hollow subsequently used by a Galah (Figure 31).

(iii) Breakage by females. Several eggs appeared to have depressed fractures in them that looked as if they had been caused by the claws of a female that hurried out of the hollow when startled while incubating.

(iv) Predators of eggs. The goanna (*Varanus tristus*) was seen climbing into hollows on two different occasions.

During one hide watch at Coomallo Creek, a goanna was seen climbing up a tree which had a White-tailed Black Cockatoo female incubating in it. As the goanna approached the hollow entrance, the female came up and sat staring out of the hollow entrance. The goanna turned and ran down the tree immediately, then ran along the ground and up another hollow tree. As it ran up the trunk, several Galahs saw it and flew around it making a threatening noise. The goanna scurried into a hollow in the tree and periodically peered out of the hollow. The Galahs stayed nearby and threatened it each time it appeared. It did not leave the hollow until the Galahs had flown off. From the reaction of the Galahs, it would appear that the goanna is a predator of eggs and young. Pianka (1971) observed a similar incident and stated that large tree climbing lizards are a potent threat to hole nesting parrots.

Figure 31a Broken egg with dropped in sprays of leaves

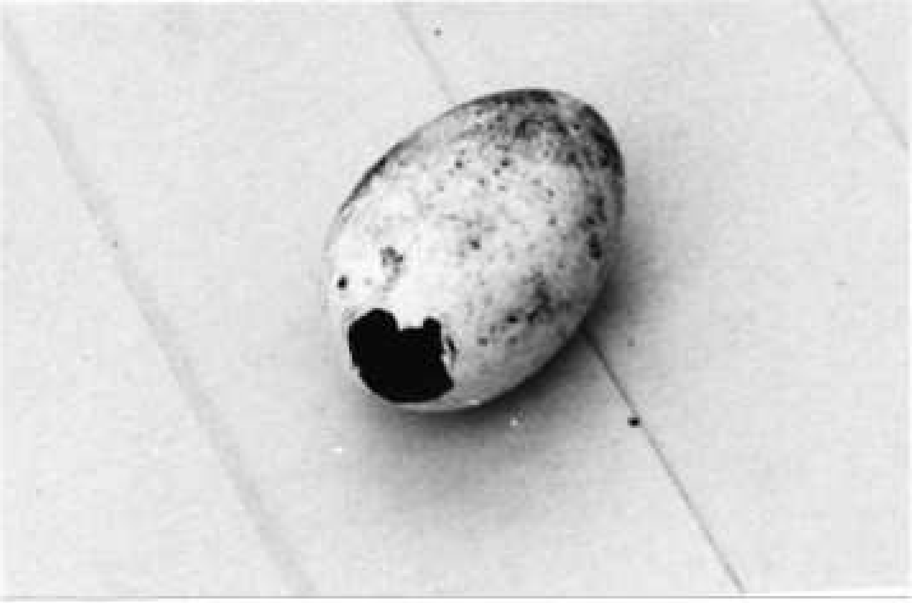

Figure 31b Base broken off egg and contents removed

Figure 31c. Two small nestlings with remains of normally hatched eggs nearby.

On another occasion at Coomallo Creek, a goanna was seen entering a small hollow which contained a Port Lincoln Parrot's nest. There was much squawking from inside and then silence. The hollow could not be inspected, unfortunately, to see the damage.

In other areas, possums (Trichosurus sp.) may also be potential predators of eggs. At Moornaming two nests were found with broken eggs and in both, possums were sheltering in the hollow.

The accidental loss of an egg usually affects the whole clutch and results in the failure of that nesting attempt.

5.4.11 Repeat laying. There was only one known re-laying at Manmanning and nine at Coomallo Creek. All of these instances involved tagged individuals and there were probably other attempts that could not be verified.

An attempt at re-laying was always carried out in another nest hollow but usually in one close by. Of the ten documented cases, only three were successful in fledging young. In each of the instances, the first nest had failed during incubation or very soon after hatching.

The period between failure and the subsequent attempt at re-laying was around 20 days (20, 19, 22, 21, 15-22, 14-21). One bird made a total of three nesting attempts in one breeding season. The first two failed when the small nestlings died for some reason and she successfully fledged a young after the third attempt.

There were no known cases of re-laying attempts made by females who failed after they ceased brooding their nestling continuously.

5.4.12 Breeding success in relation to laying date. At Coomallo Creek, eggs that give rise to young that leave the nest are laid throughout the laying season (Figure 26) whereas at Manmanning there is a tendency for eggs that are laid late in the season to be unsuccessful (Figure 27). As there is no difference in hatching success between clutches at either area then this tendency at Manmanning must be due to some factor acting on the population in such a way that it results in more failures amongst nestlings from late eggs.

The breeding data at Coomallo Creek have been examined to see if there is a reduction in clutch size late in the laying season and to see if birds nesting early in the season are more successful. There were too few data at Manmanning to examine. The laying season has been divided into four-weekly laying periods (i.e. Period A consists of the first four weeks after laying starts) and the clutch size and fledging success within the laying seasons 1970 to 1976 have been calculated and shown on Table 27.

In all years except 1976 there is a trend of decreasing clutch size as the season progresses and in most years there is a trend of decreasing breeding success as the season progresses. In those years where there were pairs who fledged both young from the nest, these usually took place in the first half of the season.

5.5 Daily routine. The daily routine of nesting pairs from laying of eggs to departure of young from the nest was determined from hide observations and from casual observations made during the collection of nest data.

TABLE 27

Fledging of Coomallo Creek young
in relation to laying dates.

Year	Laying period †	No. of nests	Clutch size	No. fledged/pair
1971	A	23	1.87	0.78
	B	32	1.75	0.50
1972	A *	29	1.86	0.76
	B	20	1.75	0.65
1973	A	33	1.73	0.55
	B	19	1.53	0.63
1974	A *	12	1.92	1.08
	B *	33	1.82	0.82
	C	20	1.50	0.60
1975	A *	32	1.88	0.59
	B *	31	1.81	0.71
	C	21	1.81	0.57
1976	A	17	1.71	0.82
	B *	32	1.88	0.81
	C	14	1.86	0.71

† (Period A : first 4 weeks after laying starts.
(Period B : next 4 weeks.
(Period C : remainder of laying period.

* Denotes 2 nestlings fledged from one nest in this period.

The daily routine of females at six nests over two years at Coomallo Creek is represented graphically in Figure 32. During incubation the female remains in the hollow except when the male returns at mid-morning and dusk to feed her. She may also spend a brief period with him at dawn. The longest period spent outside the hollow at this stage by any of the females was just under one hour made up of 11 minutes mid-morning and 42 minutes at dusk. This pattern continued after hatching until the nestling was about 10 days old.

After this the female would leave with the male at dawn and go out feeding with the flock, returning at mid-morning and spending the remainder of the time in the hollow. The period that the female was absent from the hollow gradually increased until the nestling was between three and four weeks old and from then on, the female spent all day feeding with the male, returning at mid-morning and dusk to feed the nestling. She still brooded the nestling from dusk to dawn.

It was during this period that the males were first seen entering the hollows and feeding the nestlings. Some males did not feed the nestling directly but fed the female after she had fed the nestling and she went back into the hollow and fed the nestling again. There was considerable individual variation between males; some never fed their nestlings, some fed irregularly, and some fed regularly.

From three to four weeks until eight to nine weeks, this pattern continued with females brooding only at night. From eight to nine weeks until fledging, the females ceased brooding at night and entered

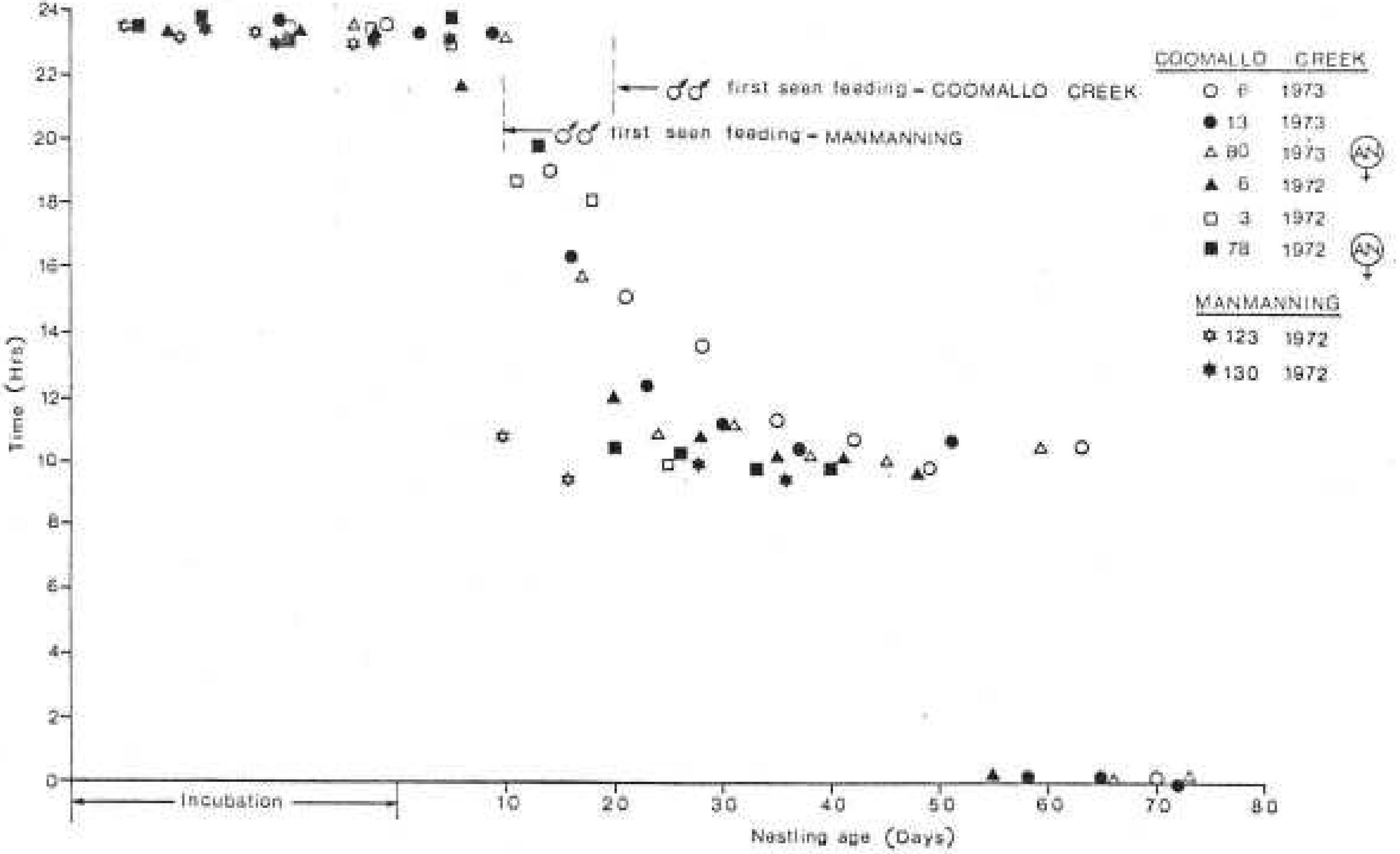

Figure 32. Total time spent in nest hollow by six females from Coomallo Creek and two from Manmanning.

the hollow only to feed the nestling at mid-morning and at dusk. The total time spent in the hollow at this stage was less than 20 minutes.

The daily routine of two nests at Manmanning during 1972 is shown on Figure 32. Although both of these nests failed, casual observations throughout the period of the study revealed that this routine was quite typical of nests at Manmanning.

By the time the nestlings at Manmanning were 10 days old, the females were leaving at dawn and apart from the mid-morning feed, not returning until dusk. The birds at Coomallo Creek very seldom failed to return at mid-morning to feed the nestlings but at Manmanning the birds very often did not return at this time. Often males at Manmanning failed to return mid-morning while their females were incubating.

As the nestlings at Manmanning got older, it was usual for the birds to leave at dawn and return only at dusk to feed the nestlings.

The males at Manmanning began to feed the nestlings as soon as the females ceased brooding during the day which was at about 10 days. In this area, at all the nests watched, males did not fail to feed the nestlings directly.

In both areas, once the nestlings left the hollow, the family did not return to the area of the hollow.

5.6 Nestlings.

5.6.1 Nestling period. This term is taken to cover the period from hatching until the nestling leaves the nest hollow and flies off with its parents (fledges).

The descriptive changes in nestlings between hatching and fledging are shown in Figures 33a-33f. Table 28 presents data on the nestling period and shows it to occur between 72 and 80 days after hatching.

5.6.2 Growth.

5.6.2.1 Introduction. Five different measurements made on nestlings each time they were handled were selected for analysis:-

(a) Length of culmen.
(b) Length of left tarsus.
(c) Length of tail.
(d) Weight.
(e) Length of folded left wing.

All five were measured for 1970 and 1971 and thereafter only the last two were measured. It was found that nestling weight gave a reasonable indication of an individual's prospects for fledging and that length of the folded left wing gave an accurate method for aging nestlings.

There were enough data from Coomallo Creek and Manmanning for weight and length of folded wing comparisons between years, within

Figure 33a. 0-1 week. Nestling hatches covered with pale yellow down, is blind and helpless with a prominent egg tooth.

Figure 33b. 1-2 weeks. Eyes still closed, egg tooth present and if touched nestling will beg immediately.

Figure 33c. 2-3 weeks. Eyes open and feathers burst through the skin in all tracts. Nestling appears greyish because of feather sheaths under the down.

Figure 33d. 3-4 weeks. Maxilla may develop grey stripes. Down feathers are lost progressively as feathers burst out of sheaths. Tail emerges and cheek patch appears.

Figure 33e. 5-6 weeks. Well covered with black feathers. May be some tufts of down or some feathers. Cheek patch well defined and white tail "window" begins to appear.

33f. 7-8 weeks. White window on tail is now clearly visible.

TABLE 28

Nestling period (days) based on nest visits to 197 nests.
Data from Coomallo Creek and Manmanning.

Nestling period (days)	Minimum period (No. of clutches)	Maximum period (No. of clutches)
70	12	
71	17	
72	13	1 *
73	16	3
74	23	4
75	14	4
76	12	18
77	5	12
78	3	12
79	5	11
80	2	16
81	1	14
82		16
83	1	12
84	1	10
85		
86	1	
87		
88		
89	1 †	
90		

* Shortest maximum nestling period

† Longest minimum nestling period

Accurately known nestling periods:
1 at 72 days
1 at 75 days
3 at 76 days
1 at 79 days
1 at 80 days

areas and between areas, both overall and within years. As some nestlings were only measured once and others measured up to nine times before leaving the nest, it has not been possible to fit growth curves to each individual nestling, so the data have been pooled to allow growth curves to be constructed and comparisons to be made.

Growth curves have been fitted using methods set out by Ricklefs (1967, 1968) and in each case it was found that the best fit for the data was the logistic curve which has the form:-

$$\text{Weight (or length of folded left wing)} = \frac{a}{1 + e^{-kt}}$$

where 'a' is the asympotote of the curve (and in both cases this was given the value of the mean adult weight or mean adult length of folded left wing, for nestling weight and nestling folded left wing respectively); 'k' is a constant which is proportional to the overall growth rate, and 't' is time.

Ricklefs (1967) set out methods and conversion factors which allow a straight line conversion of the logistic equation to be constructed. The slope of the straight line is directly proportional to the rate constant of the logistic equation (and, therefore, to the growth rate).

Ricklefs states that 'The selection of these equations does not imply that they have any biological significance, or that they are realistic models of the growth process, but merely that they are well-suited for comparative descriptive purposes and have been found to approximate the growth curves of many kinds of organisms'. Provided that the curves are found to be reasonable approximations it is possible to compare growth rates for different seasons or areas by comparing the slopes of the straight line conversions and testing them statistically with a 't-test'.

Usually the age of a nestling could be determined to within two or three days but because nest hollows were not inspected daily and the hatching dates not known with certainty, the nestlings were divided into age groups of 0-1, 1-2, 2-3, ... weeks which comprise nestlings with an age of 0-7, 8-14, 15-21, ... days respectively. For the purposes of plotting graphs each age group was given a plotting day and this coincided with the middle of the age group; 0-1 weeks was plotted at four days, 1-2 weeks plotted at 11 days, etc.

5.6.2.2 Length of culmen. There were only small numbers of nestlings at Manmanning so only the measurements of Coomallo Creek nestlings for 1970 and 1971 were pooled and used in this analysis and the analyses of tail and tarsus.

The mean, ranges and standard deviation of culmen length for each age group are given in Table 29. There is a steady increase in culmen length from about 45 per cent of adult length at two to three weeks until fledging at 10-11 weeks when it is about 90 per cent of adult length. Nestling culmen length plotted as a percentage of adult length is shown in Figure 34.

5.6.2.3 Length of tail. The data for length of tail are shown on Table 30 and there is a steady increase from its first appearance at two to three weeks to 85 per cent of adult length

TABLE 29

Coomallo Creek (1970/71) : Culmen length

Age (weeks)	No. in sample (n)	Mean culmen length (mm) $(\bar{x})$		Standard deviation (s)	Range	Mean as a % of adult culmen (44.2 mm)
1 - 2						
2 - 3	1				20.9	47
3 - 4	15	23.1	Λ	2	20.8 - 25.4	52
4 - 5	18	26.7	Λ	1	24.3 - 28.7	60
5 - 6	27	29.8	Λ	1	27.0 - 33.1	67
6 - 7	24	32.1	Λ	1	29.2 - 35.2	73
7 - 8	37	34.3	Λ	2	29.7 - 37.7	78
8 - 9	24	37.0	Λ	2	32.9 - 40.5	84
9 - 10	34	38.2	Λ	1	35.4 - 40.0	86
10 - 11	29	39.8	"	1	37.8 - 42.0	90
11 - 12	5	39.6		2	37.6 - 41.3	90

Λ Top value significantly less than lower one.

" No significant difference.

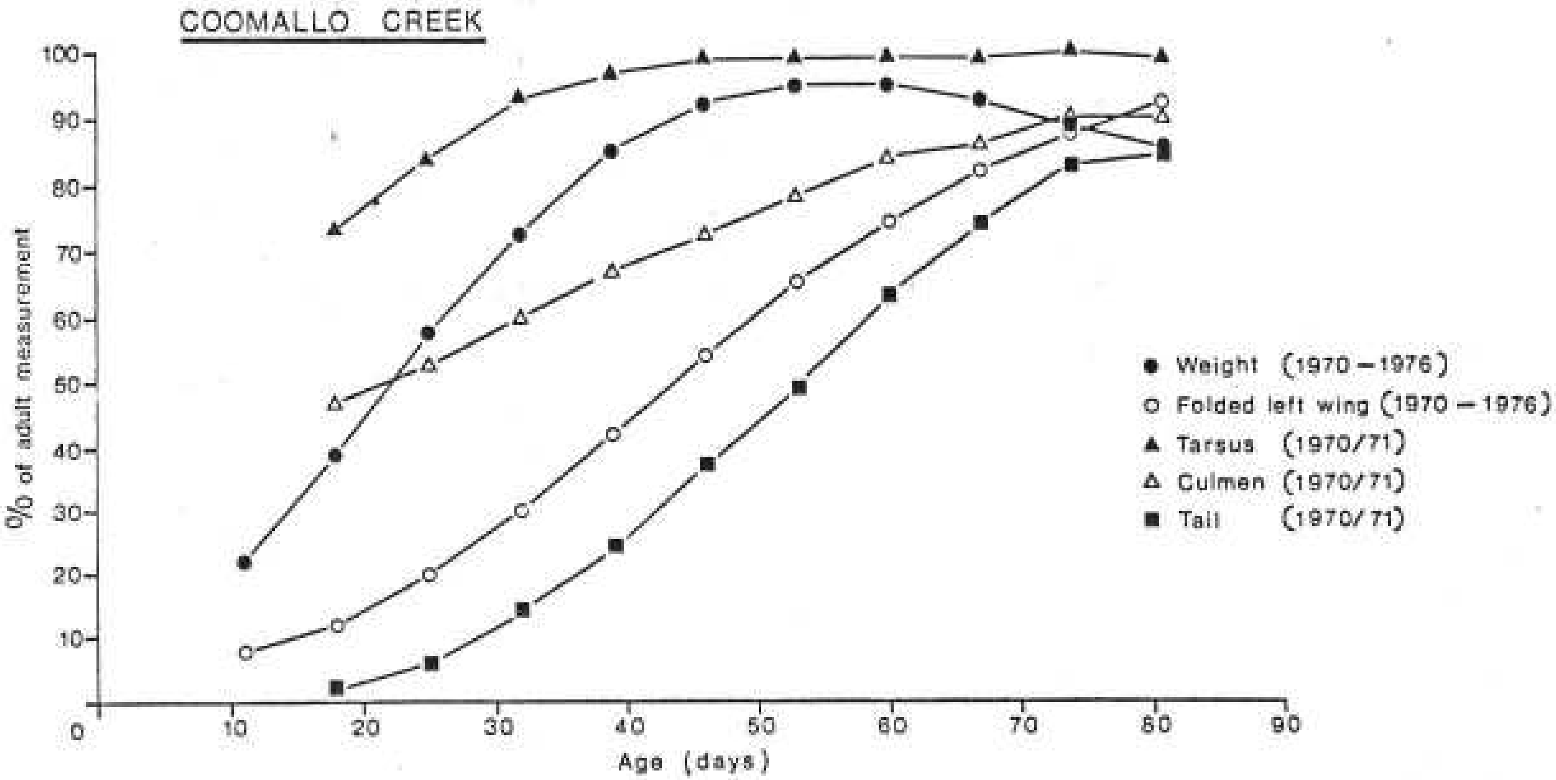

Figure 34. Coomallo Creek nestling measurements as a percentage of mean adult measurements.

TABLE 30

Coomallo Creek (1970/71) : Tail length

Age (weeks)	No. in sample (n)	Mean tail length (mm) ($\bar{x}$)		Standard deviation (s)	Range	Mean as a % of adult tail (286 mm)
1 - 2						
2 - 3	1				6	2
3 - 4	15	18	∧	7	9 - 32	6
4 - 5	18	40	∧	11	19 - 60	14
5 - 6	27	70	∧	13	51 - 94	24
6 - 7	24	106	∧	17	62 - 124	37
7 - 8	37	140	∧	19	86 - 172	49
8 - 9	24	179	∧	17	141 - 211	63
9 - 10	34	211	∧	14	188 - 243	74
10 - 11	29	236	"	12	211 - 252	83
11 - 12	5	243		12	223 - 256	85

∧ Top value significantly less than lower one.

" No significant difference.

by fledging. Tail length plotted as a percentage of adult length is shown on Figure 34.

5.6.2.4 Length of tarsus.

The data for length of tarsus shows that it increases very rapidly (Table 31) until four to five weeks when it reaches adult length and the chick is able to stand properly. It is possible to band White-tailed Black Cockatoo nestlings any time from four weeks old.

Tarsus length plotted as a percentage of adult length is shown on Figure 34.

5.6.2.5 Nestling weight.

(i) Manmanning. The data for nestling weight for 38 nestlings from Manmanning (1970 to 1976) are pooled and shown on Table 32 and Figure 35. The mean, ranges and standard deviation for each age group are shown, as is the coefficient of variation (V) which is 100 x the standard deviation divided by the mean. This was used by Visser (1974) as a good absolute measure for the variation within a single age group.

The coefficient of variation for nestling weight at Manmanning was high and precluded the use of the logistic curve for the area from 1970 to 1976 so that comparisons could not be made between years.

Nestling weight at Manmanning rose to a peak of 82 per cent of adult weight by eight to nine weeks and dropped back to 74-80 per cent at fledging.

(ii) Coomallo Creek. The data for nestling weights of 335 nest-

TABLE 31

Coomallo Creek (1970/71) : Tarsus length

Age (weeks)	No. in sample (n)	Mean tarsus length (mm) $(\bar{x})$		Standard deviation (s)	Range	Mean as a % of adult tarsus (39.6 mm)
1 - 2						
2 - 3	1				29.0	73
3 - 4	15	33.1	∧	2	30.0 - 36.0	84
4 - 5	18	36.9	∧	2	34.0 - 39.3	93
5 - 6	27	38.5	"	1	36.0 - 40.0	97
6 - 7	24	39.1	"	1	35.3 - 40.5	99
7 - 8	37	39.1	"	1	37.5 - 42.2	99
8 - 9	24	39.1	"	1	36.0 - 40.2	99
9 - 10	34	39.2	"	1	37.0 - 41.4	99
10 - 11	29	39.6	"	1	38.6 - 41.3	100
11 - 12	5	39.3		1	38.6 - 40.0	99

∧ Top value significantly less than lower one.

" No significant difference.

TABLE 32

Manmanning (1970-76) : Nestling weight

Age (weeks)	No. in sample (n)	Mean weight (g) ($\bar{x}$)	Standard deviation (s)	Coefficient of variation (%) (v)	Range	Mean as % of adult weight (658 g)
1 - 2	2	140			110 - 170	21
2 - 3	9	236	39	17	180 - 310	36
3 - 4	14	332	74	22	200 - 460	50
4 - 5	21	420	81	19	270 - 560	64
5 - 6	24	475	94	20	290 - 610	72
6 - 7	23	508	96	19	300 - 660	77
7 - 8	27	515	96	19	360 - 710	78
8 - 9	24	541	87	16	380 - 700	82
9 - 10	22	540	92	17	390 - 750	82
10 - 11	24	527	67	13	360 - 650	80
11 - 12	9	488	53	11	430 - 600	74

Number of nestlings = 38

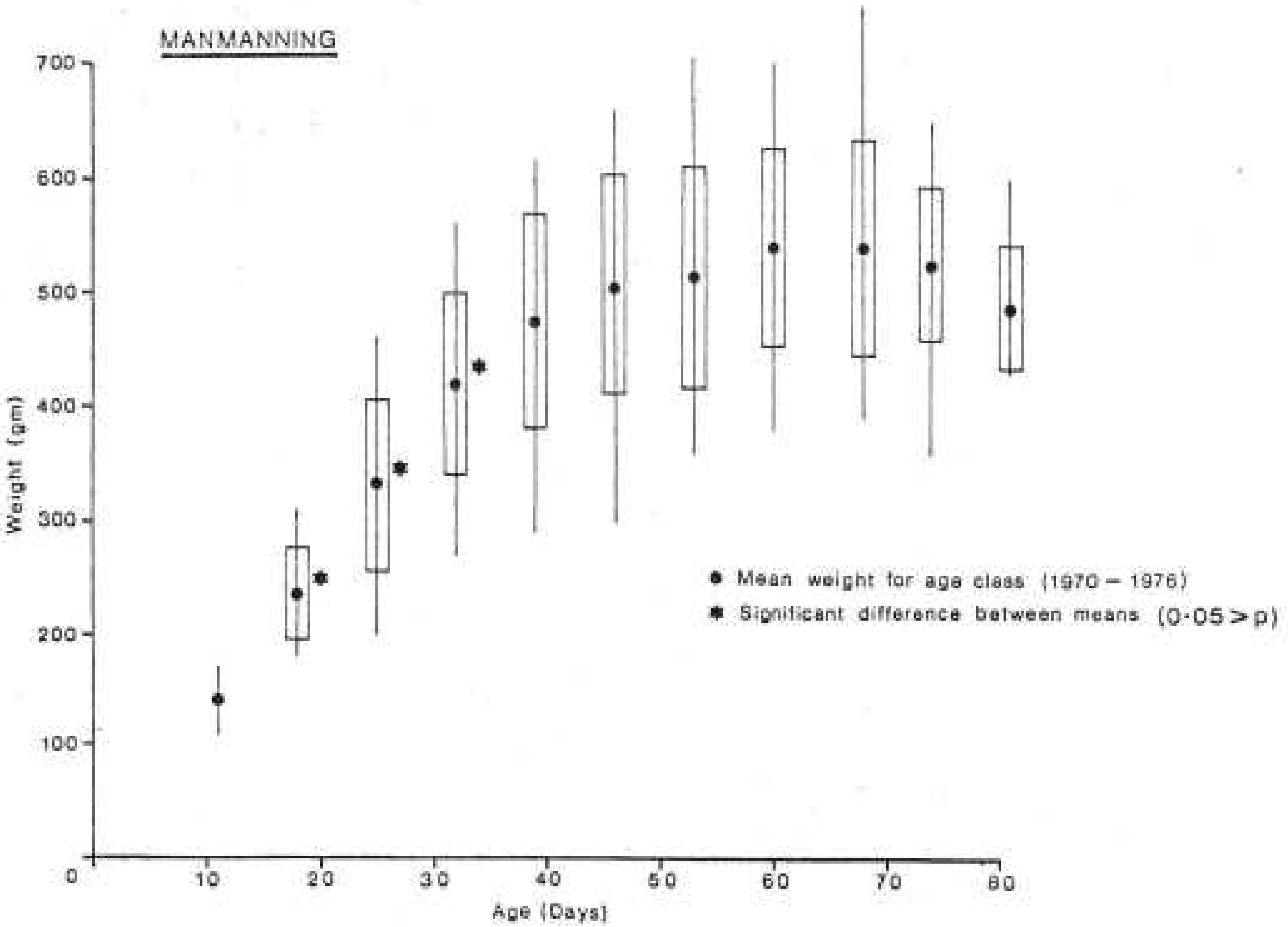

Figure 35. Manmanning nestling weight (1970-1976). Vertical line represents range; rectangle is standard deviation either side of mean.

lings from Coomallo Creek from 1970 to 1976 is shown on Table 33 and plotted on Figure 36. Nestling weight increases to 95 per cent of adult weight at seven to eight weeks and drops back to 86-89 per cent at fledging. The coefficient of variation decreases from quite high at 25 per cent at one to two weeks to only 6 per cent at fledging. The pattern in individuals measured from hatching to fledging was of an increase in weight to a maximum around 50 to 60 days after which the weight dropped off; this meant that the logistic curve, where it could be fitted, would only hold until the weight reached a peak. For this reason it was only applied to the data up to 55 days and was found to be significant (0.001 > P). The fitted curve is shown on Figure 36.

The age of 21 nestlings was accurately known and the weights for these individuals are shown on Figure 37. A logistic equation was fitted and found to be significant (0.001 > P) and it is plotted on the figure as are the mean weights for each age group for the area from 1970 to 1976. The growth curves for the known aged nestlings and all nestlings in age groups were converted to logistic factors. There was no significant difference in the regression coefficients, therefore, no significant difference in growth rates for the two curves. From this it appears that the process of grouping nestlings whose ages are not accurately known was valid.

(iii) Comparison between Coomallo Creek and Manmanning. The comparison between nestling weights for different age groups at Coomallo Creek and Manmanning is shown on Table 34. By the time they were three to four weeks old Coomallo Creek nestlings were significantly heavier than Manmanning nestlings and remained so until fledging.

TABLE 33

Coomallo Creek (1970-76) : Nestling weight

Age (weeks)	No. in sample (n)	Mean weight (g) ($\bar{x}$)	Standard deviation (s)	Coefficient of variation (%) (v)	Range	Mean as % of adult weight (658 g)
1 - 2	7	147	37	25	90 - 210	22
2 - 3	97	260	61	23	130 - 480	39
3 - 4	153	382	65	17	170 - 580	58
4 - 5	155	477	61	13	250 - 700	72
5 - 6	169	562	55	10	390 - 760	85
6 - 7	160	608	54	9	380 - 720	92
7 - 8	169	631	56	9	490 - 780	95
8 - 9	155	631	54	9	400 - 740	95
9 - 10	156	616	55	9	400 - 740	93
10 - 11	107	589	43	7	510 - 710	89
11 - 12	17	571	36	6	480 - 620	86

Number of nestlings = 335

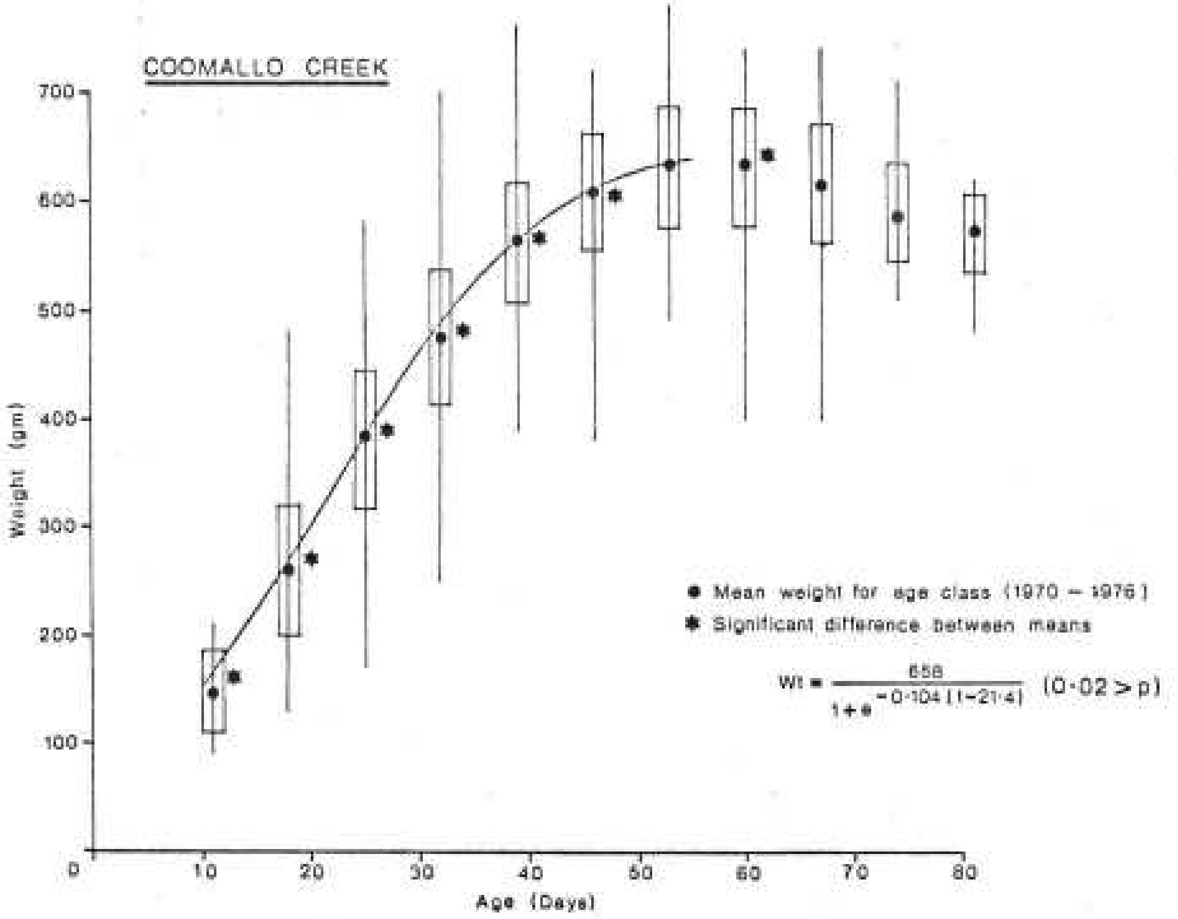

Figure 36. Coomallo Creek nestling weight (1970-1976).

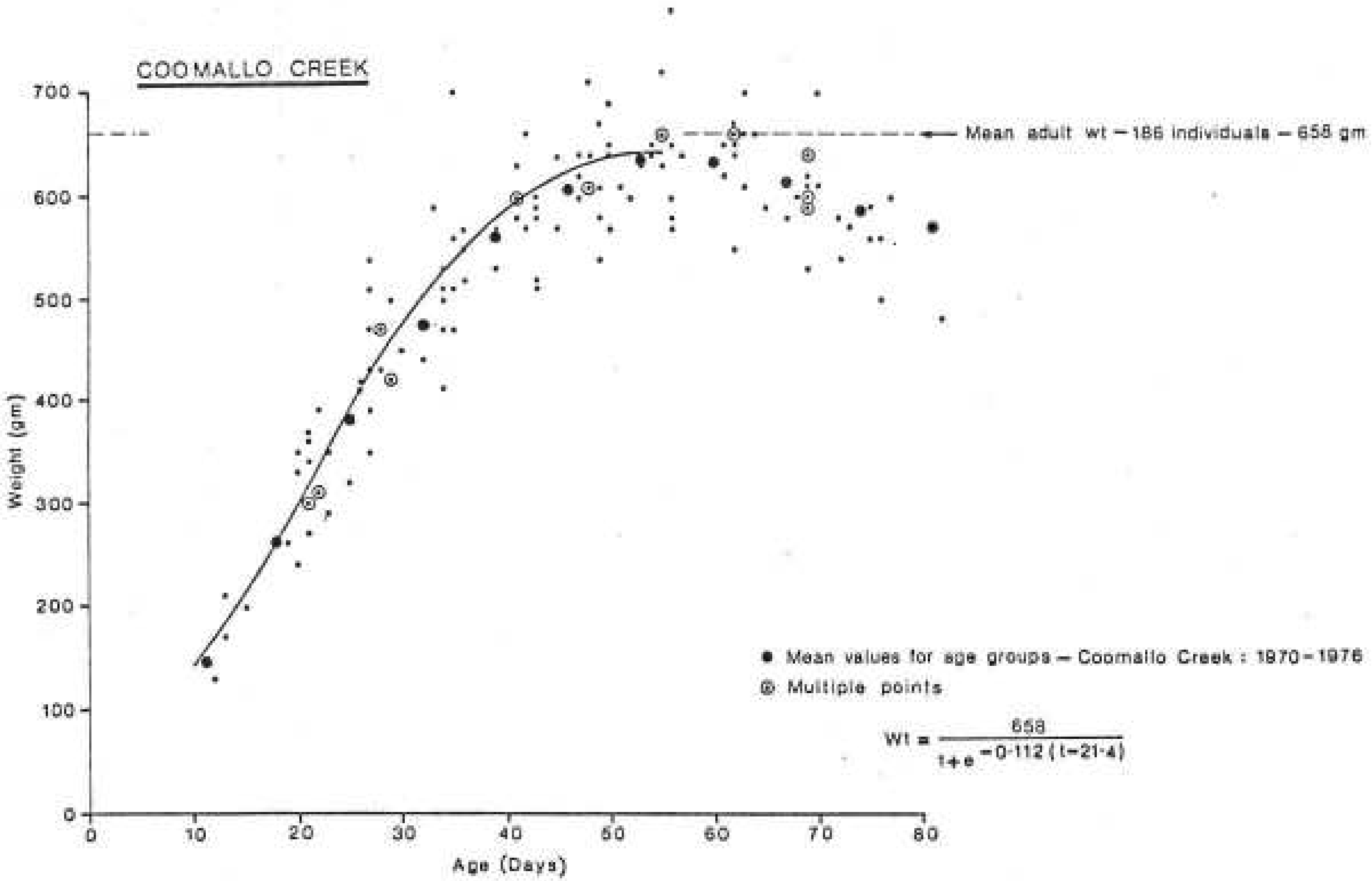

Figure 37. Weight of 21 known age nestlings at Coomallo Creek.

TABLE 34

Nestling weight (1970-76) : Comparison between Coomallo Creek and Manmanning

	MEAN WEIGHT (g)		SAMPLE NUMBERS		STANDARD DEVIATION		Comparison between means
Age class	Coomallo	Manmanning	Coomallo	Manmanning	Coomallo	Manmanning	(t) or (d) *
1 - 2	147	140	7	2	37		
2 - 3	260	236	97	9	61	39	d_{12} = 1.71 NS
3 - 4	382	332	153	14	65	74	t_{14} = 2.69 Sig
4 - 5	477	420	155	21	61	81	d_{23} = 3.10 Sig
5 - 6	562	475	169	24	55	94	d_{25} = 4.41 Sig
6 - 7	608	508	160	23	54	96	d_{24} = 4.87 Sig
7 - 8	631	515	169	27	56	96	d_{28} = 6.12 Sig
8 - 9	631	541	155	24	54	87	d_{26} = 4.90 Sig
9 - 10	616	540	156	22	55	92	d_{23} = 3.75 Sig
10 - 11	589	527	107	24	43	67	d_{27} = 4.30 Sig
11 - 12	571	488	17	9	36	53	t_{24} = 4.74 Sig

* "d-tests" were used where the variances for the two samples were not equal.

Coomallo Creek nestlings reached a peak weight of about 630 grams by seven to eight weeks whereas Manmanning nestlings peaked at only 540 grams a week later; i.e. 14 per cent lighter by 16 per cent later.

(iv) Coomallo Creek comparison between years. The data for nestling weight for age groups each year 1970 to 1976 are shown on Table 35. Data for 1975 and 1976 are limited as each nestling was measured only once in 1975 and twice in 1976 whereas in other years they were measured each time the nest hollow was inspected. The data for each year from Table 35 were used to calculate logistic curves for each year and each of these was found to be significant ($0.001 > P$ in each case). The converted growth curves for each year are shown on Figure 38 and there were no significant differences in growth rates between any of the years.

(v) Growth rate in relation to time of laying. As mentioned earlier the laying season at Coomallo Creek was divided up into four-weekly laying periods. The converted growth curves for each period in 1971, 1972, 1973, 1974 and 1976 were calculated and compared. There were insufficient data in 1970 and 1975 to make this type of comparison. In only two of the years examined was there any difference in growth rates between periods. In 1972 the growth rate in Period B was significantly ($0.001 > P$) less than Period A, and in 1973 Period C was significantly ($0.002 > P > 0.001$) less than the earlier two periods. The converted growth curves for hatching periods in 1972 and 1973 are shown on Figures 39 and 40.

TABLE 35

Coomallo Creek (1970-76) : Weight [Means for sample (No. in sample)]

Only successful nestlings used : Total No. of measurements made = 1,345

	1970	1971	1972	1973	1974	1975	1976	1970-76
1 - 2					136 (5)			147 (7)
2 - 3			269 (26)	257 (18)	252 (36)	242 (5)	277 (11)	260 (97)
3 - 4		370 (13)	378 (35)	385 (36)	386 (39)	366 (9)	398 (19)	382 (153)
4 - 5	497 (7)	437 (11)	464 (33)	485 (38)	494 (36)	462 (21)	489 (9)	477 (155)
5 - 6	574 (11)	561 (16)	549 (35)	560 (41)	577 (39)	542 (13)	571 (14)	562 (169)
6 - 7	636 (9)	625 (15)	591 (39)	614 (40)	610 (38)	585 (8)	613 (11)	608 (160)
7 - 8	641 (14)	644 (22)	606 (39)	621 (42)	653 (35)		642 (17)	631 (169)
8 - 9	652 (11)	634 (13)	603 (32)	639 (43)	635 (42)		641 (14)	631 (155)
9 - 10	615 (13)	634 (21)	589 (31)	621 (46)	626 (31)		605 (13)	616 (156)
10 - 11	575 (17)	596 (11)	593 (17)	592 (29)	588 (33)			589 (107)
11 - 12		587 (6)	568 (4)	547 (3)	570 (4)			571 (17)
No. of nestlings used	25	40	49	46	68	57	50	335

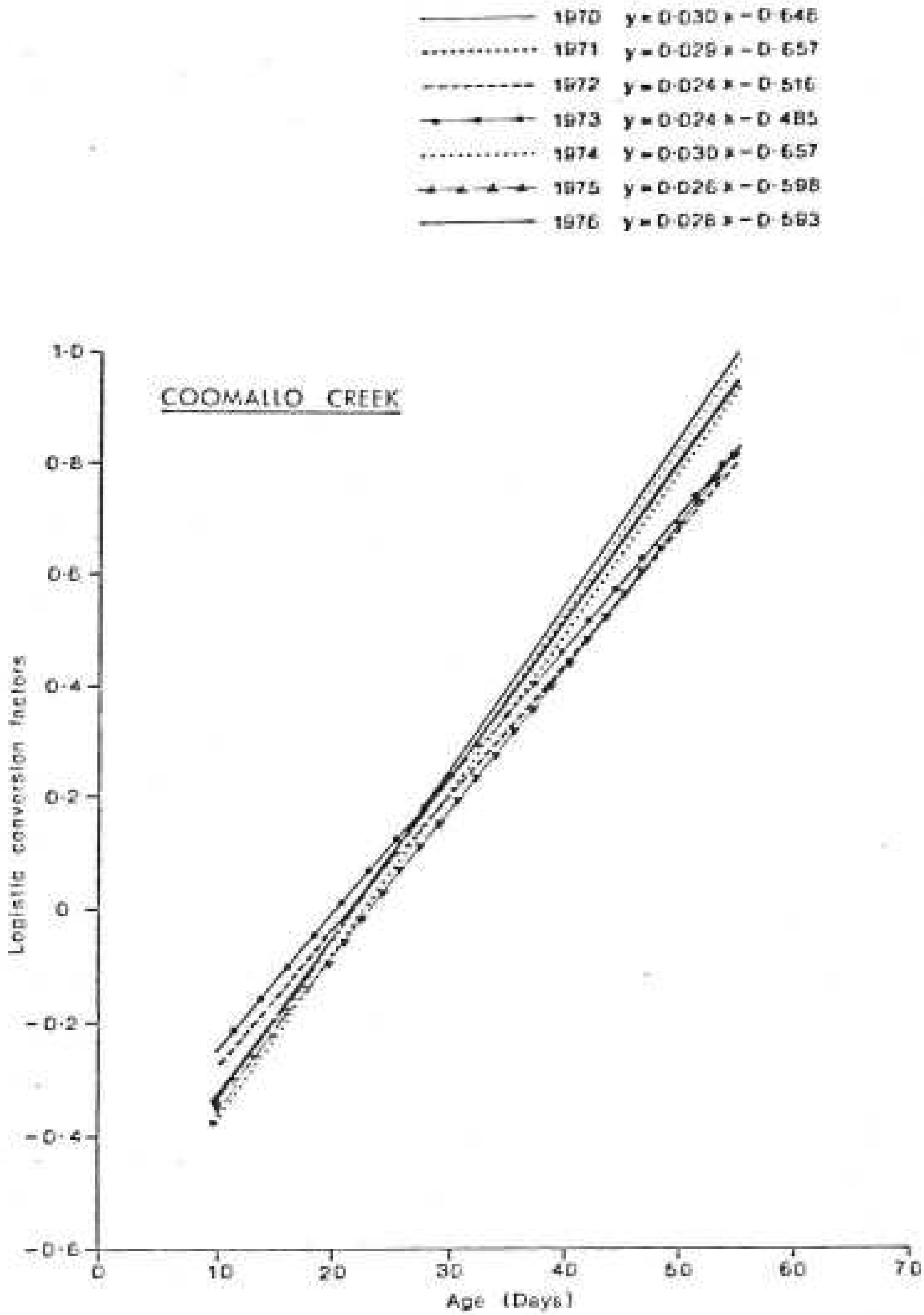

Figure 38. Coomallo Creek. Converted growth curves for nestling weight each season 1970-1976.

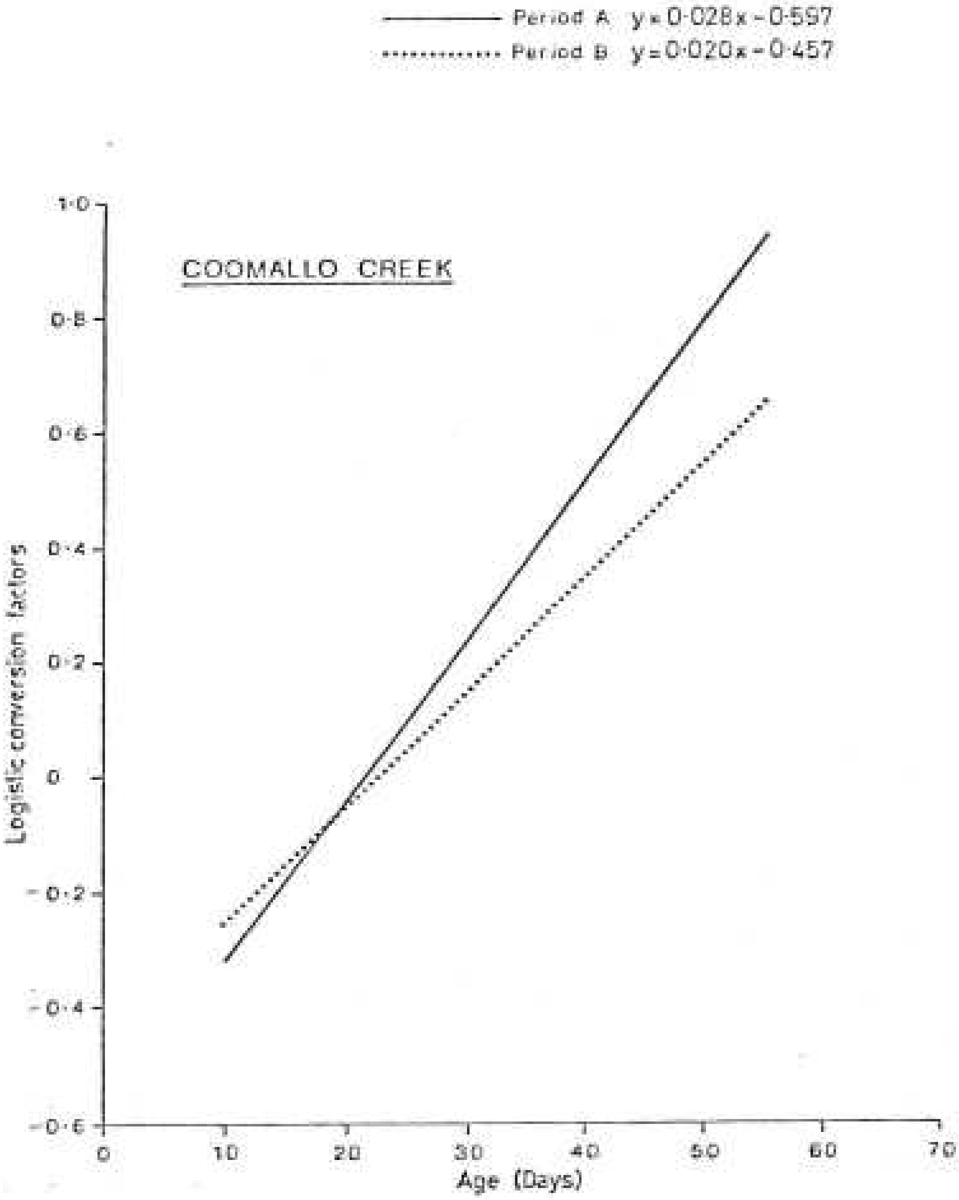

Figure 39. Coomallo Creek. Converted growth curves for nestling weight for laying periods A and B in 1972.

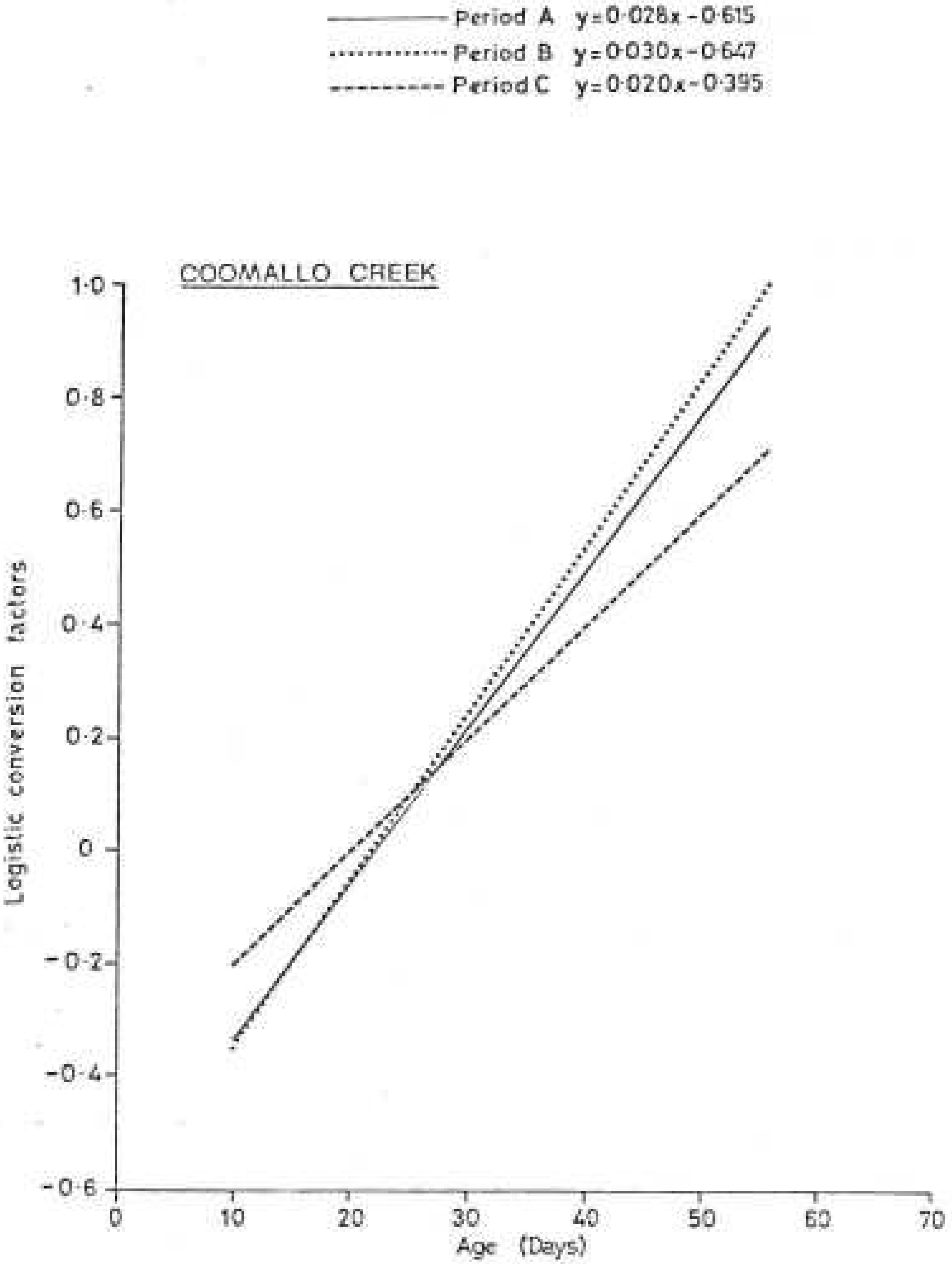

Figure 40. Coomallo Creek. Converted growth curves for nestling weight for laying periods, A, B and C in 1973.

(vi) Manmanning individual nestling weights. There were 59 nestlings measured over the seven years at Manmanning. The growth curves for each individual have been examined and the growth curves for all nestlings for whom there were at least three measurements are shown for 1973 and 1974 on Figures 41 and 42. In each of these figures the mean measurements for Coomallo Creek nestlings (1970-1976) are shown to illustrate the difference between the nestlings of the two areas. The years illustrated were included as they show the range of weights characteristic of the other years not illustrated. Of all seven years, in only three of them, i.e. 1971, 1973 and 1974, did any nestling have a weight growth curve that was similar to the normal Coomallo Creek curve. In 1971 there were four individuals that did so and in the other two years only one individual. These individuals were all among the first laid in their particular year. The remaining 92 per cent of nestlings at Manmanning had weight growth curves that were less than the normal curve for Coomallo Creek.

5.6.2.6 Length of folded left wing.

(i) Coomallo Creek. The data for length of folded left wing for nestlings at Coomallo Creek 1970 to 1976 are shown on Table 36 and plotted on Figure 43, together with the fitted logistic growth curve (significance 0.001 > P). In this case the logistic curve fits the data throughout the nestling period.

The length of folded left wing of 21 known age nestlings is shown plotted on Figure 44 together with the fitted logistic growth curve (significance 0.001 > P). The means of each age group for the area 1970 to 1976 are also plotted.

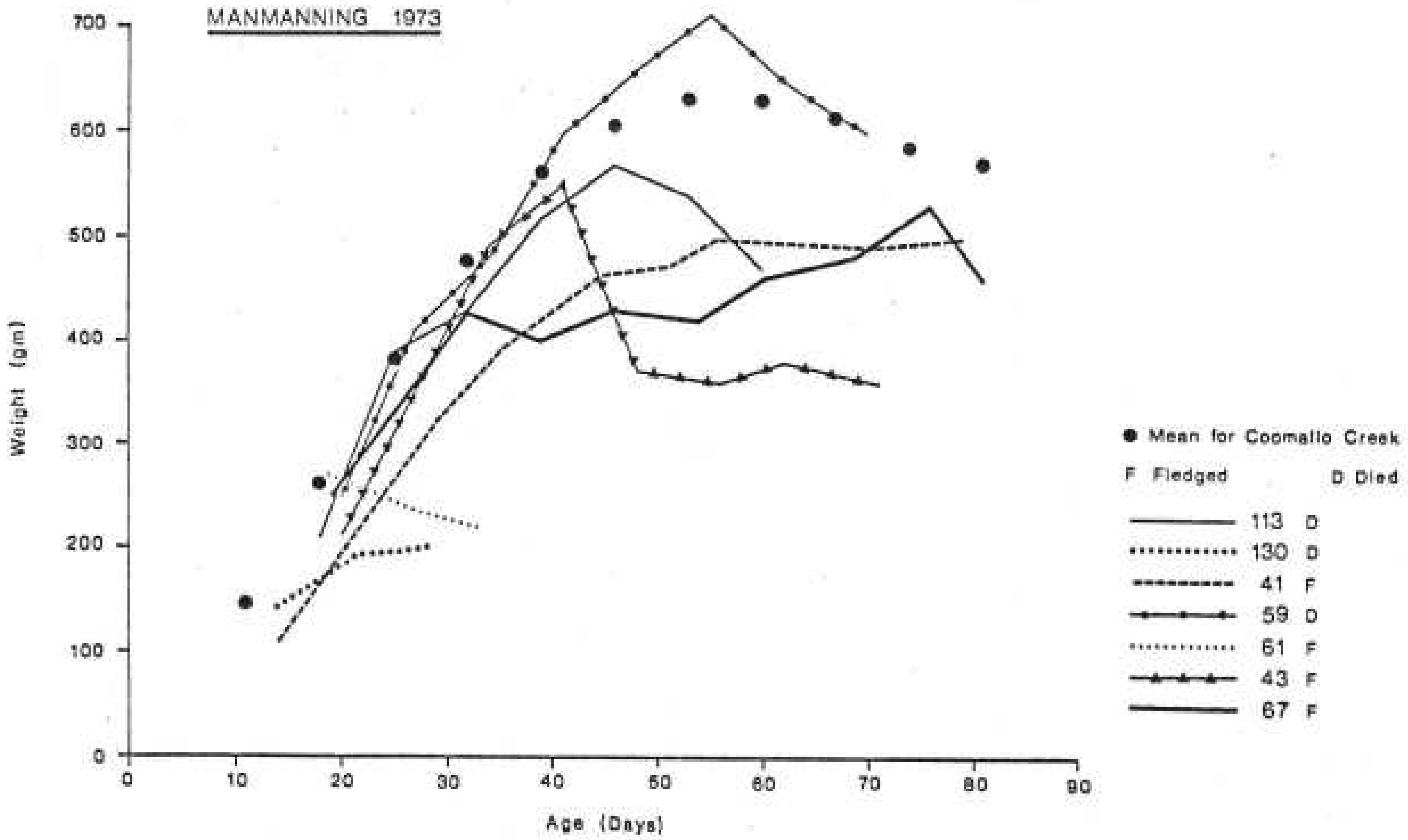

Figure 41. Manmanning 1973. Individual nestling weight curves. Numbers refer to nest number and D indicates nestling died; F indicates nestling fledged.

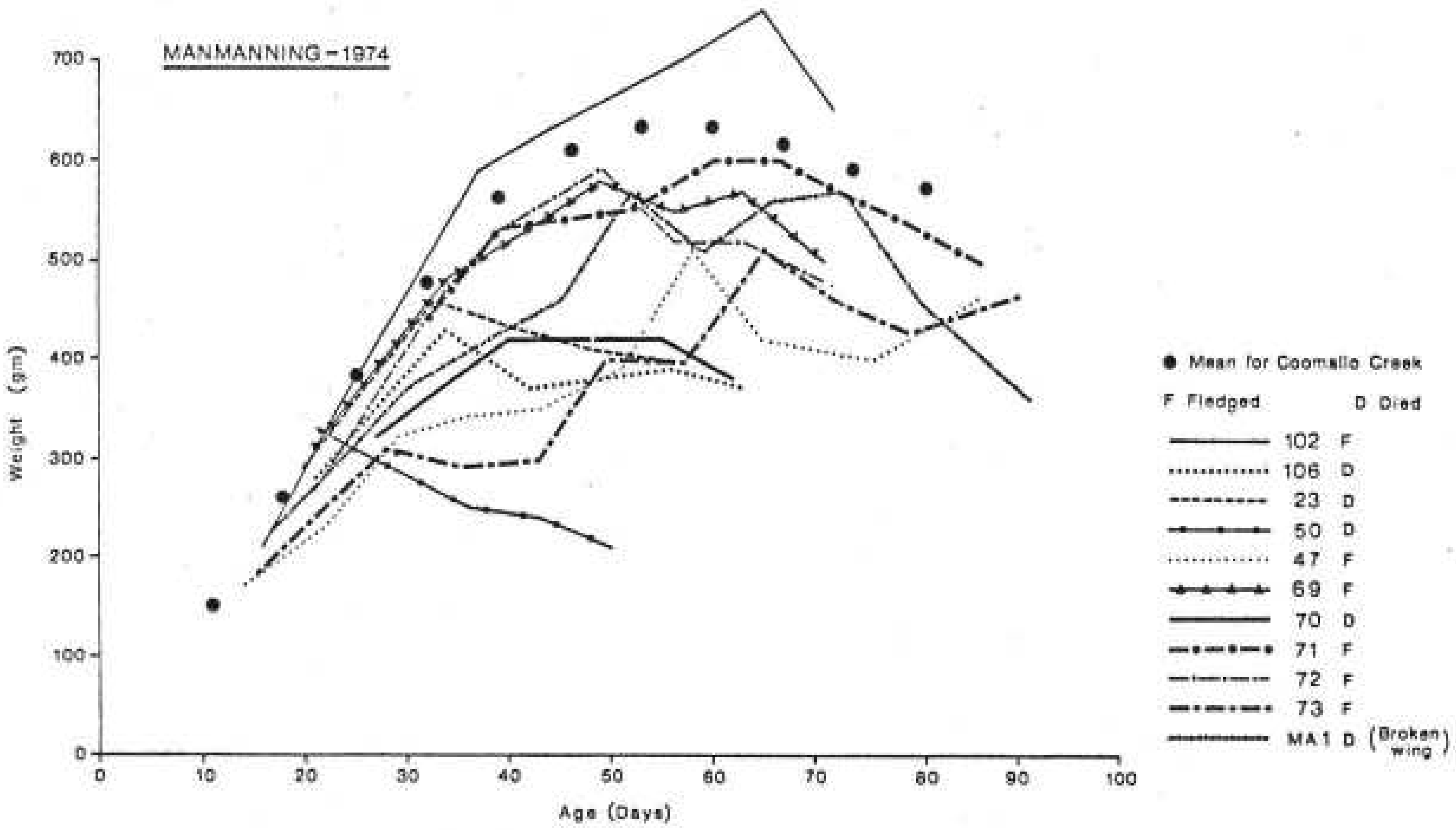

Figure 42. Manmanning, 1974. Individual nestling weight curves.

TABLE 36

Coomallo Creek (1970-76) : Nestling folded left wing

Age (weeks)	No. in sample (n)	Mean wing length (mm) ($\bar{x}$)	Standard deviation (s)	Coefficient of variation (%) (v)	Range	Mean as a % of adult wing (366 mm)
1 - 2	7	29.7	5	17	25 - 40	8
2 - 3	97	45.3	9	19	27 - 64	12
3 - 4	154	71.6	15	21	41 - 112	20
4 - 5	155	110.5	18	16	71 - 178	30
5 - 6	169	155.5	17	11	128 - 209	42
6 - 7	158	197.8	18	9	152 - 239	54
7 - 8	176	236.8	19	8	170 - 278	65
8 - 9	156	271.4	16	6	222 - 325	74
9 - 10	158	301.2	13	4	262 - 334	82
10 - 11	106	323.0	11	3	292 - 343	88
11 - 12	18	336.4	7	2	320 - 354	92

Number of nestlings = 335

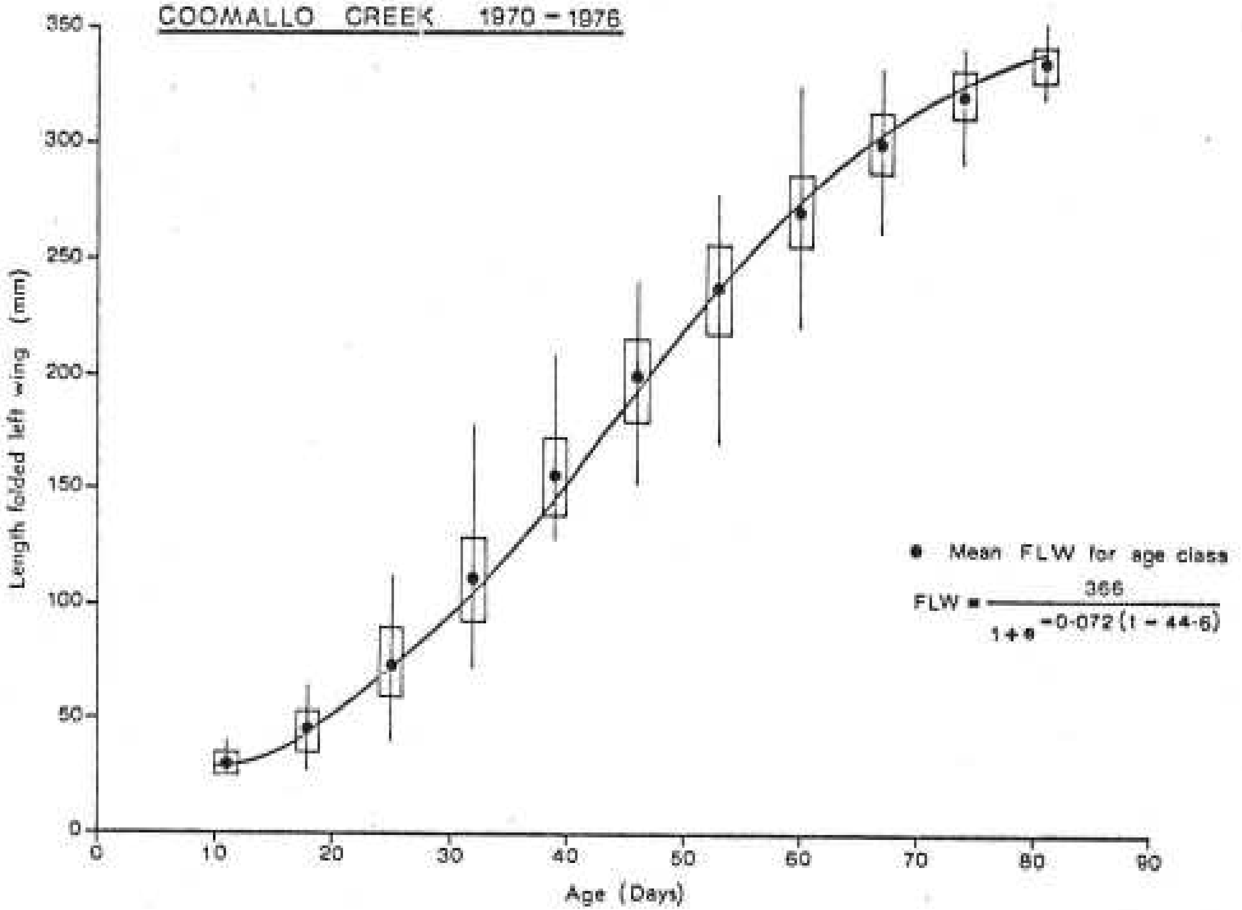

Figure 43. Coomallo Creek nestlings 1970-1976. Growth curves for length of folded left wing.

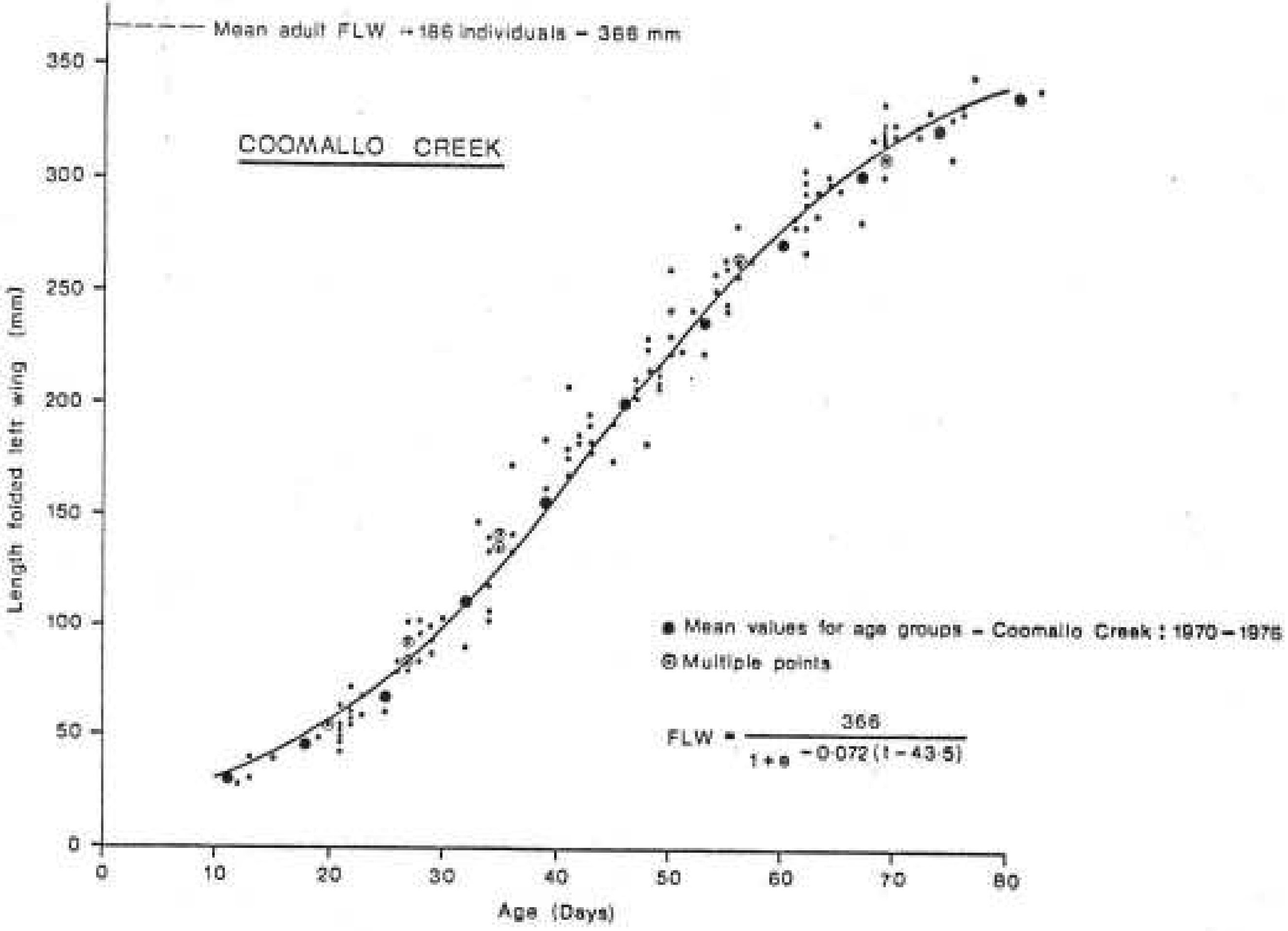

Figure 44. Coomallo Creek. Growth curve for length of folded left wing of known age nestlings.

There were no significant differences in growth rate between known age birds and all nestlings from the area grouped into age groups. This is indicated by the fact that the growth rate constant 'k' is the same in each case and is 0.072 and again this indicates that the process of grouping nestlings in this manner was valid.

(ii) Manmanning. The data for mean, range and standard deviation of length of folded left wing for age groups at Manmanning during 1970 to 1976 are shown on Table 37. Using Ricklef's (1967) conversion factors, a converted growth curve was calculated and was a significant ($0.001 > P$) fit to the data. The data from Table 37 together with the fitted logistic curve are shown on Figure 45.

(iii) Comparisons between areas. The comparison of the length of folded wing for Coomallo Creek and Manmanning is shown on Table 38. There were no significant differences between the areas until the six to seven week age group when Manmanning nestlings were significantly smaller and remained so until fledging. They fledged when 85 per cent of adult length whereas Coomallo Creek nestlings fledged when 88 per cent. There was also more variability in Manmanning nestlings and by five to six weeks this variability was significantly different from Coomallo Creek.

Using 1970 measurements for nestlings at Tarwonga and Moornaming, growth curves were calculated. The converted growth curves for these areas are shown on Figure 46 with comparative curves for Manmanning (1970-1976) and Coomallo Creek (1970-1976). Manmanning showed a significantly ($0.02 > P > 0.01$) lower growth rate than the others but there were no other significant differences.

TABLE 37

Manmanning (1970-76) : Nestling folded left wing

Age (weeks)	No. in sample (n)	Mean wing length (mm) ($\bar{x}$)	Standard deviation (s)	Coefficient of variation (%) (v)	Range	Mean as a % of adult wing (366 mm)
1 - 2	2	29.5			27 - 32	8
2 - 3	9	40.4	6	14	32 - 55	11
3 - 4	14	69.6	14	20	42 - 96	19
4 - 5	21	103.7	21	21	65 - 156	28
5 - 6	24	147.4	22	15	98 - 185	40
6 - 7	23	183.3	26	14	128 - 221	50
7 - 8	26	219.5	26	12	152 - 260	60
8 - 9	24	255.9	21	8	194 - 279	70
9 - 10	23	289.3	21	7	242 - 315	79
10 - 11	24	310.0	24	8	255 - 339	85
11 - 12	10	320.0	24	7	280 - 350	87

Number of nestlings = 38

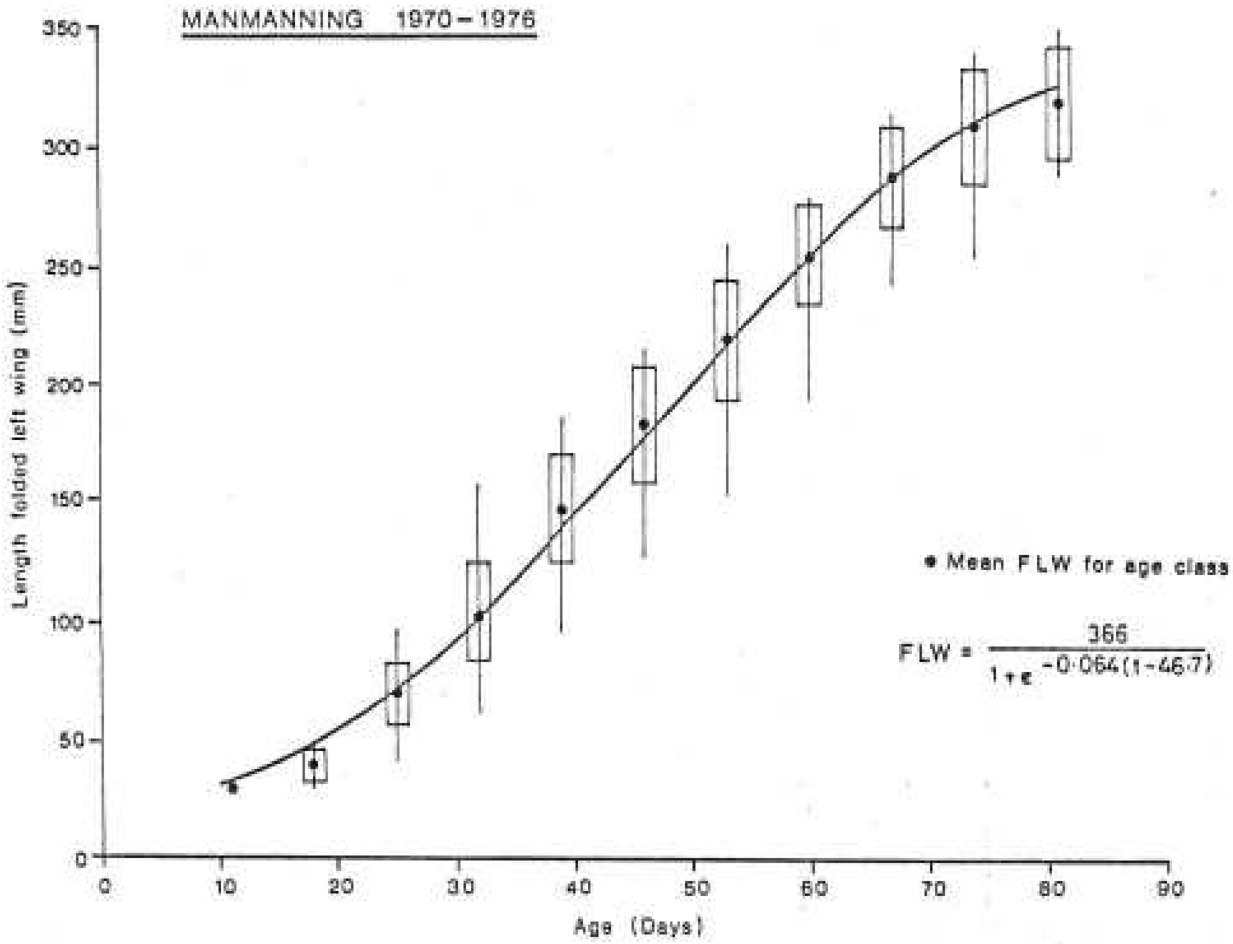

Figure 45. Manmanning nestlings 1970-1976. Growth curves for length of folded left wing.

TABLE 38

Nestling folded left wing : Comparison between Coomallo Creek (1970-76) and Manmanning (1970-76)

	MEAN FOLDED WING (mm)		SAMPLE NUMBERS		STANDARD DEVIATION		Comparison between means
Age class	Coomallo	Manmanning	Coomallo	Manmanning	Coomallo	Manmanning	(t) or (d)
1 - 2	30	30	7	2	5		
2 - 3	45	40	97	9	9	6	t = 1.67 NS
3 - 4	72	70	154	14	15	14	t = 0.48 NS
4 - 5	111	104	155	21	18	21	t = 1.58 NS
5 - 6	156	147	169	24	17	22	d_{27} = 1.70 NS
6 - 7	198	183	158	23	18	26	d_{25} = 2.54 Sig
7 - 8	237	220	176	26	19	26	d_{29} = 3.25 Sig
8 - 9	271	256	156	24	16	21	d_{28} = 3.50 Sig
9 - 10	301	289	158	23	13	21	d_{24} = 2.65 Sig
10 - 11	323	310	106	24	11	24	d_{25} = 2.57 Sig
11 - 12	336	320	18	10	7	24	d_{11} = 2.12 NS

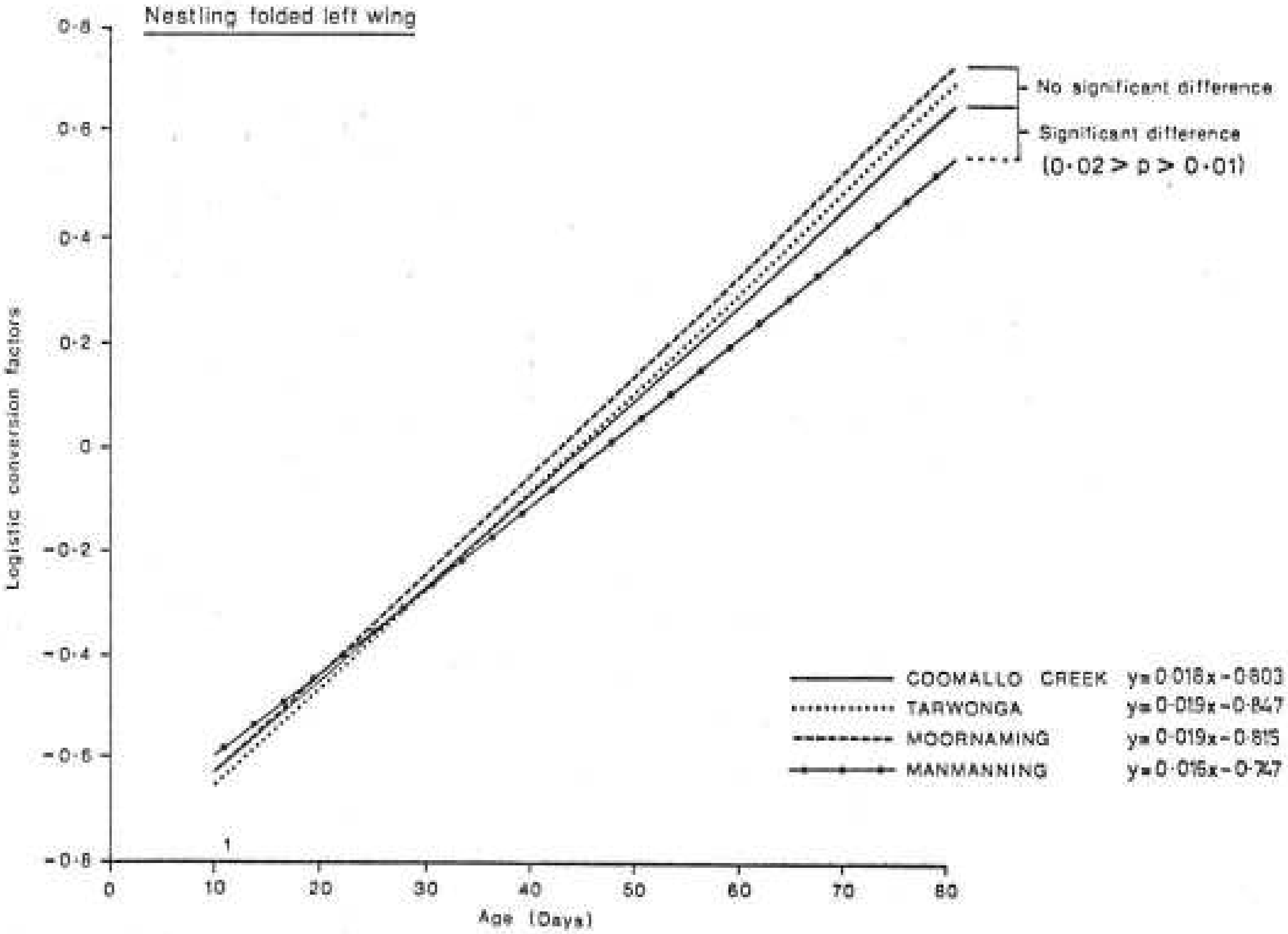

Figure 46. Converted growth curves for nestling length of folded left wing for four study areas.

(iv) Manmanning comparison between years. Only for five years were there enough data to compare nestling growth rates between years at Manmanning. The logistic equations of the growth curves for each of these years were calculated and the converted growth curves are shown in Figure 47. There were no significant differences between years.

(v) Coomallo Creek comparison between years. The logistic equations of the growth curves for the years 1970 to 1976 were calculated and the converted growth curves are shown in Figure 48. The years 1970 and 1972 had the lowest growth rates and they differ significantly from all the rest ($0.01 > P > .002$).

(vi) Coomallo Creek growth in relation to time of laying. The converted growth curves for each period in 1971, 1972, 1973, 1974 and 1976 were calculated and compared. There were insufficient data available for 1970 and 1975. There were no significant differences in growth rates between periods in any year except for 1972 when Period B had a significantly lower growth rate than Period A ($0.001 > P$). The converted growth curves for the two periods in 1972 are shown on Figure 49.

(vii) Manmanning individual nestling growth curves. The growth curves for individual nestlings at Manmanning in 1973 are plotted together with the overall growth curve for Coomallo Creek on Figure 50. This figure illustrates the wide spread of data and that despite the variability, the form of the individual growth curves is similar to Coomallo Creek although they have a slower growth rate. This differs from the effect seen in the individual nestling weight curves for the

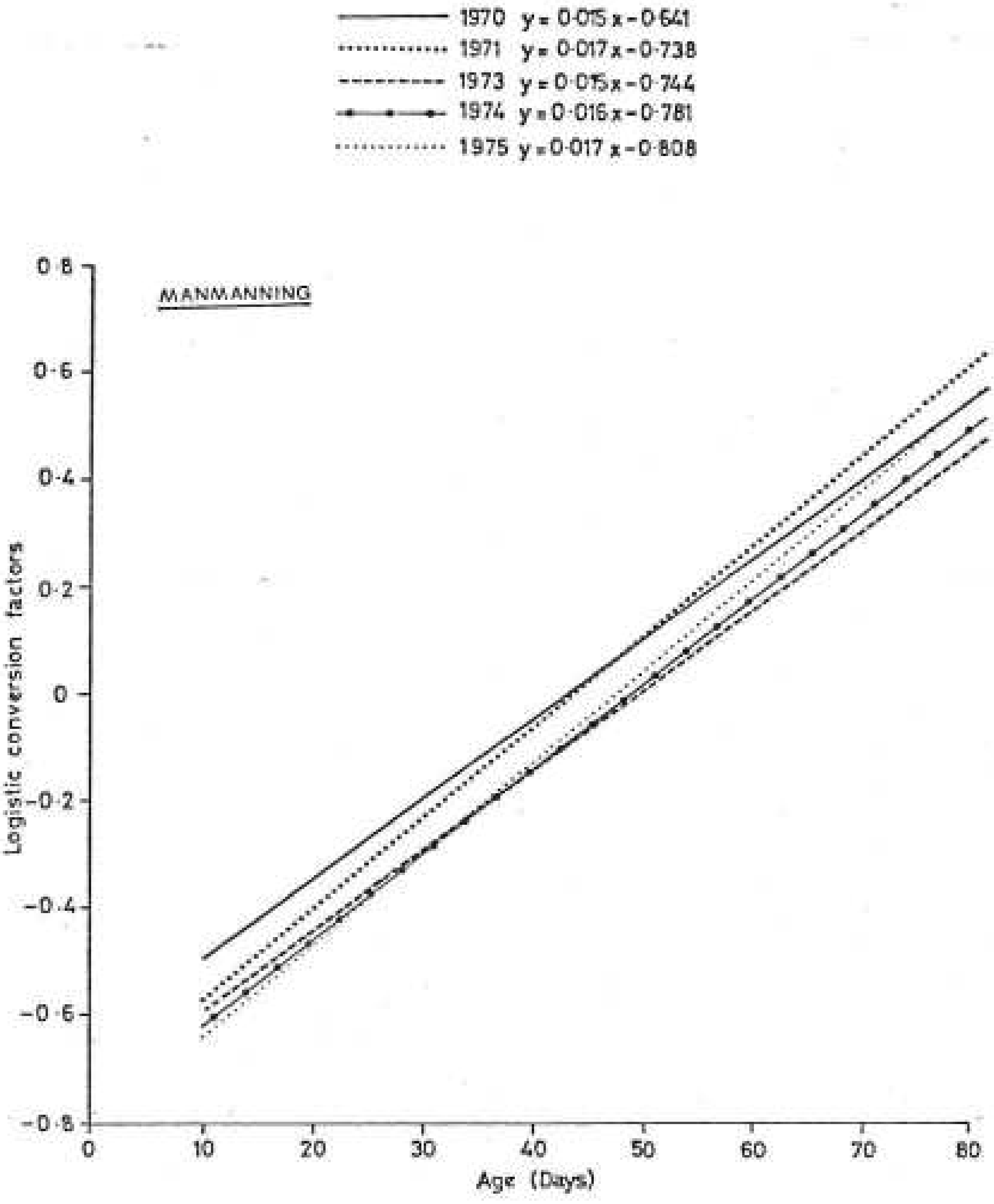

Figure 47. Manmanning. Converted growth curves for length of folded left wing of nestlings 1970-1975. There were insufficient data for 1972 and 1976.

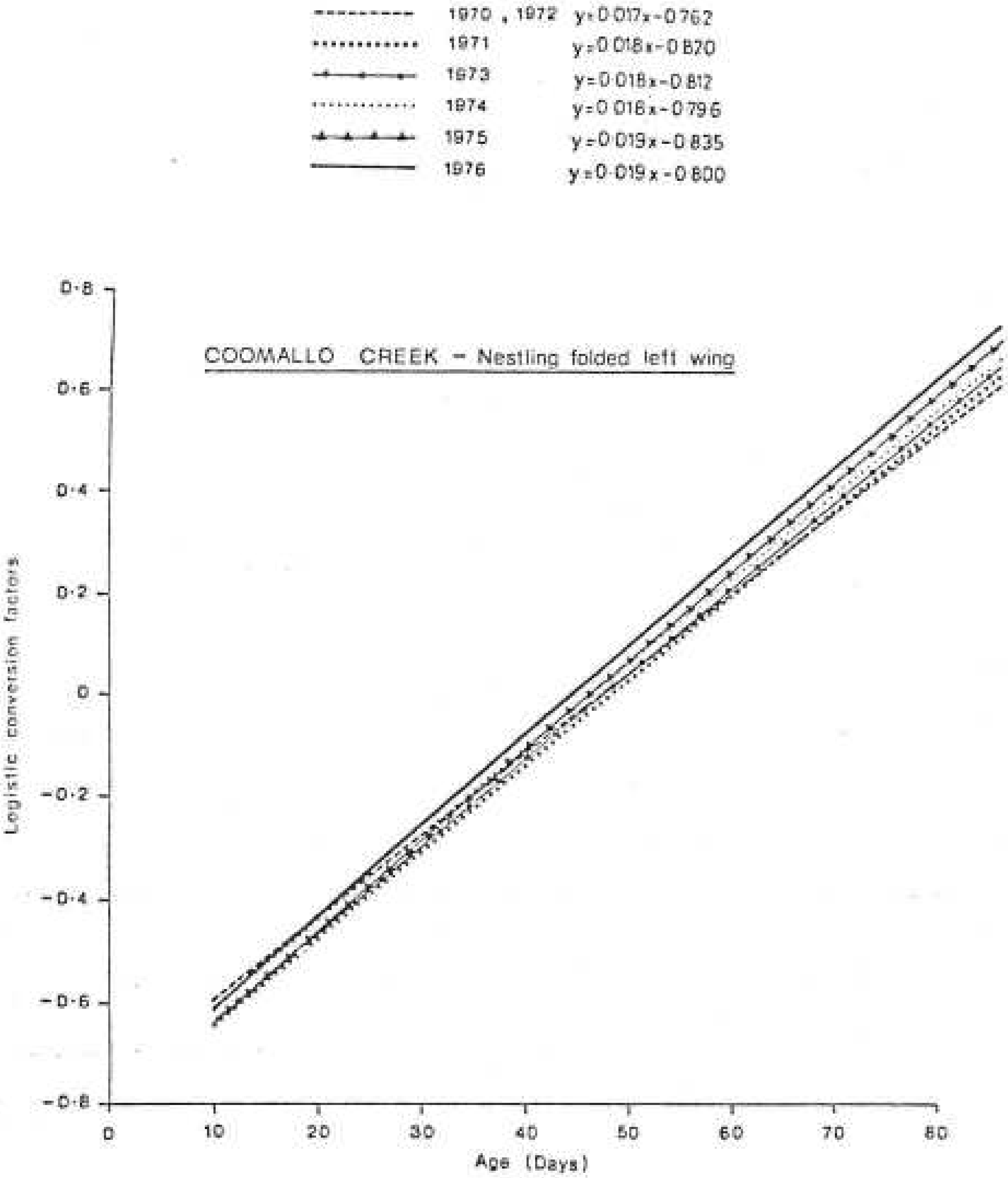

Figure 48. Coomallo Creek, 1970-1976. Converted growth curves for length of folded left wing of nestlings.

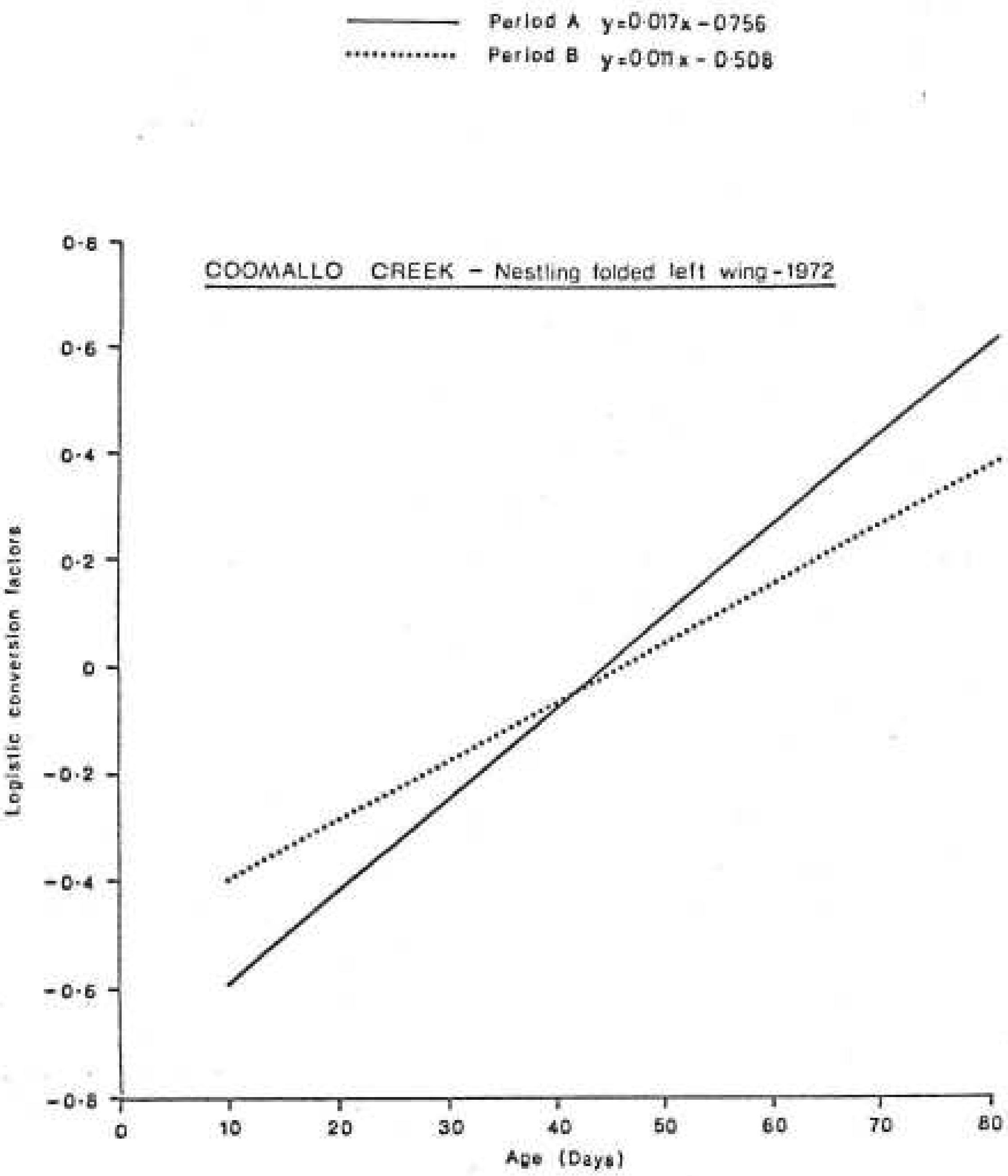

Figure 49. Coomallo Creek 1972. Converted growth curves for length of folded left wing of nestlings from laying periods A and B.

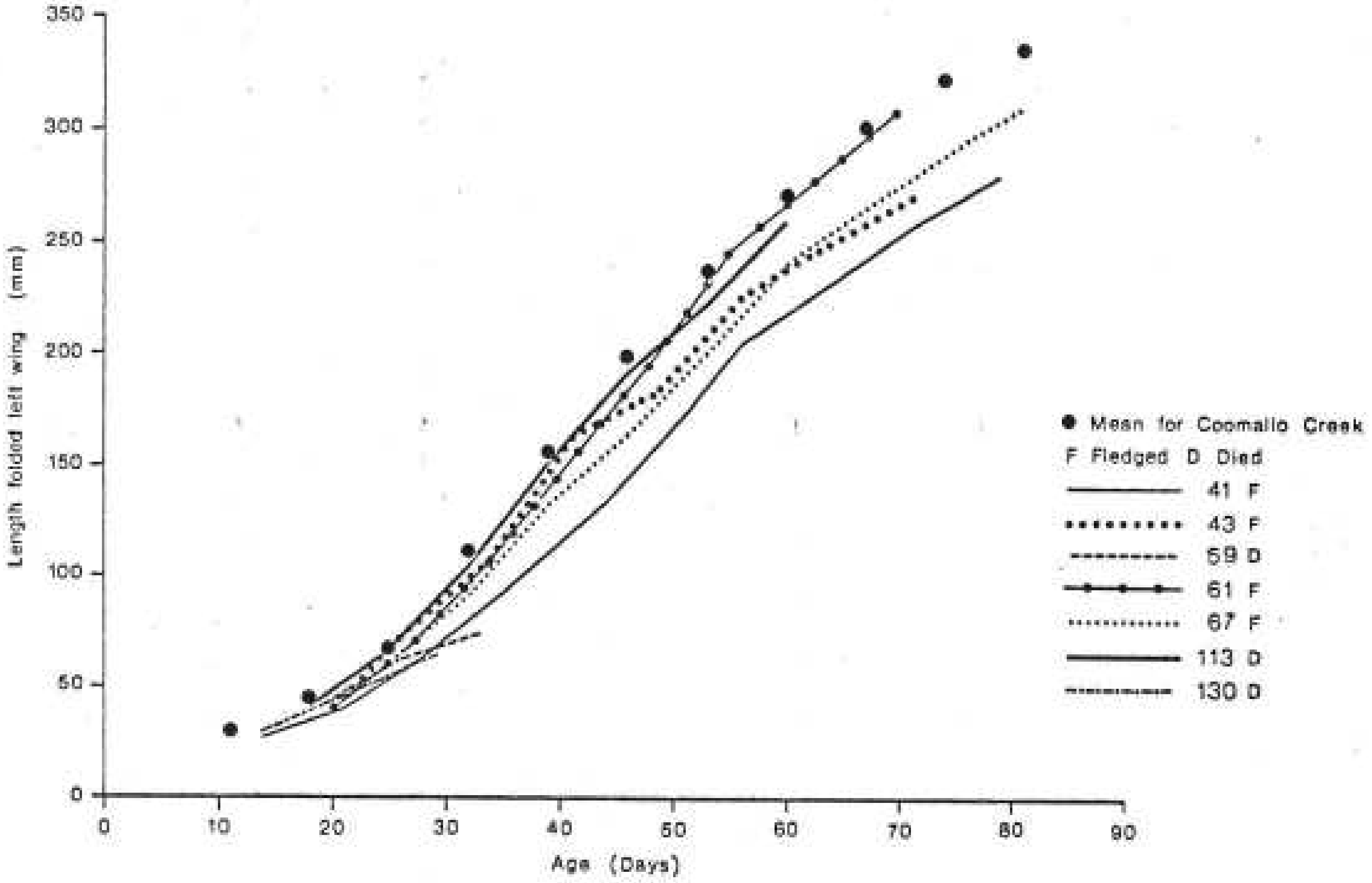

Figure 50. Manmanning 1973. Growth curves for length of folded left wing for individual nestlings.

same nestlings (Figure 41) where variation is greater than at Coomallo Creek as well as the rate being slower.

5.6.2.7 Relationship between increase in weight and increase in wing length. Visser (1974) states that 'For all young birds there is, of course, a relationship between the increase of body weight and that of wing length, although this relationship differs from species to species'. This relationship was examined for the White-tailed Black Cockatoo because it was thought that it may differ between populations from different areas and so might reveal some differences between the areas.

Using those data up to 250 mm wing length (as this is when peak weight is attained at Coomallo Creek), converted curves were made for Coomallo Creek in 1973 and Manmanning 1970 to 1976. These converted curves are plotted on Figure 51 and there was a significant difference in rate of change in weight with respect to wing length between Manmanning and Coomallo Creek with Manmanning having a lower rate ($.001 < P$).

5.6.2.8 Twins. The second nestling usually dies within 48 hours of hatching but in eight out of 222 cases at Coomallo Creek both nestlings were fledged from the nest. The second nestling hatched from 1-12 days after the first.

There were enough measurements made on three sets of twins at Coomallo Creek to enable growth curves for weight and length of folded left wing to be drawn up and these are shown for one set of twins together with the normal growth curves for the area on Figure 52. In all three cases there was very little difference in growth curves for

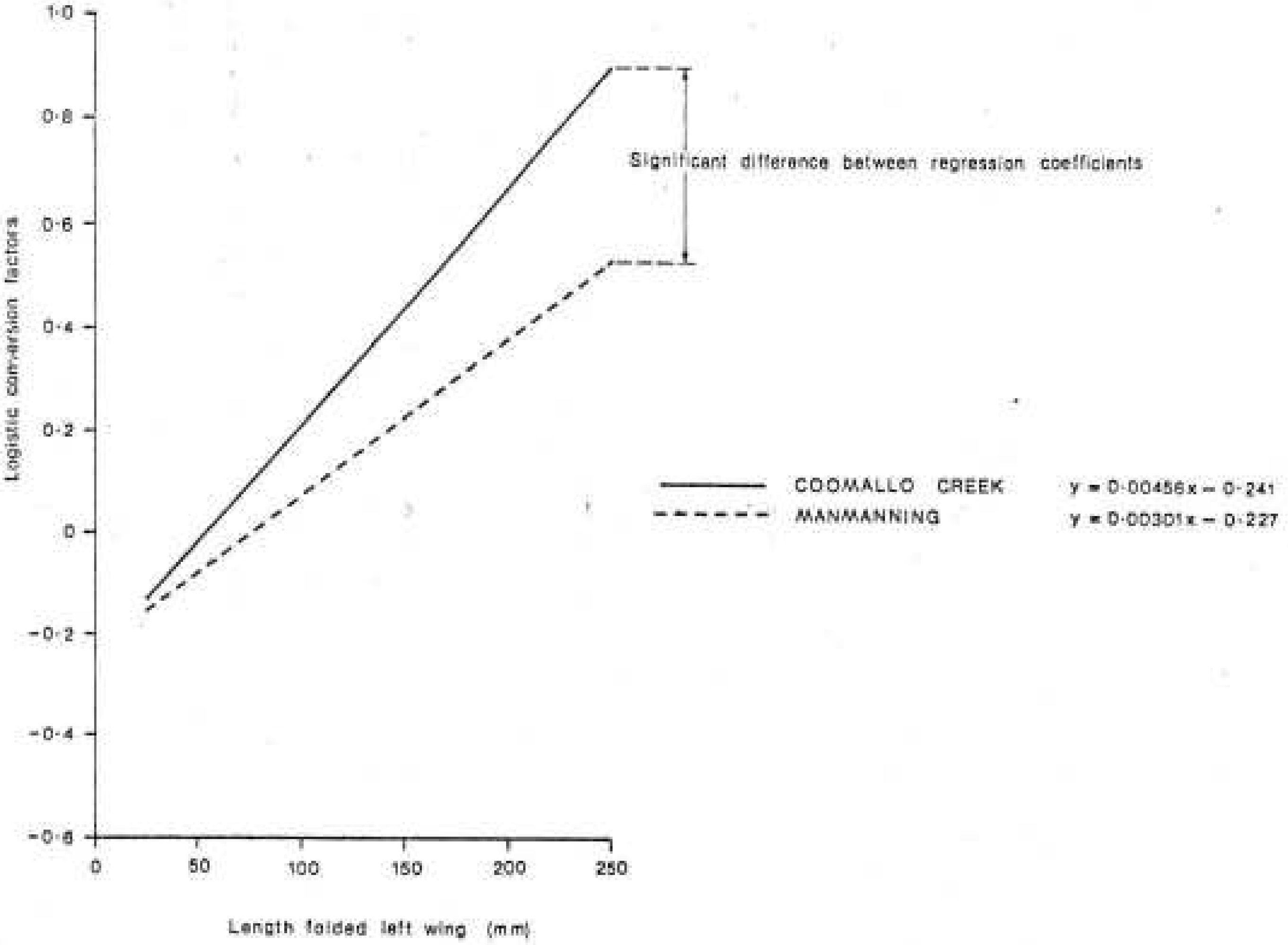

Figure 51. Converted growth curves for Manmanning and Coomallo Creek. Nestling weight plotted against length of folded left wing.

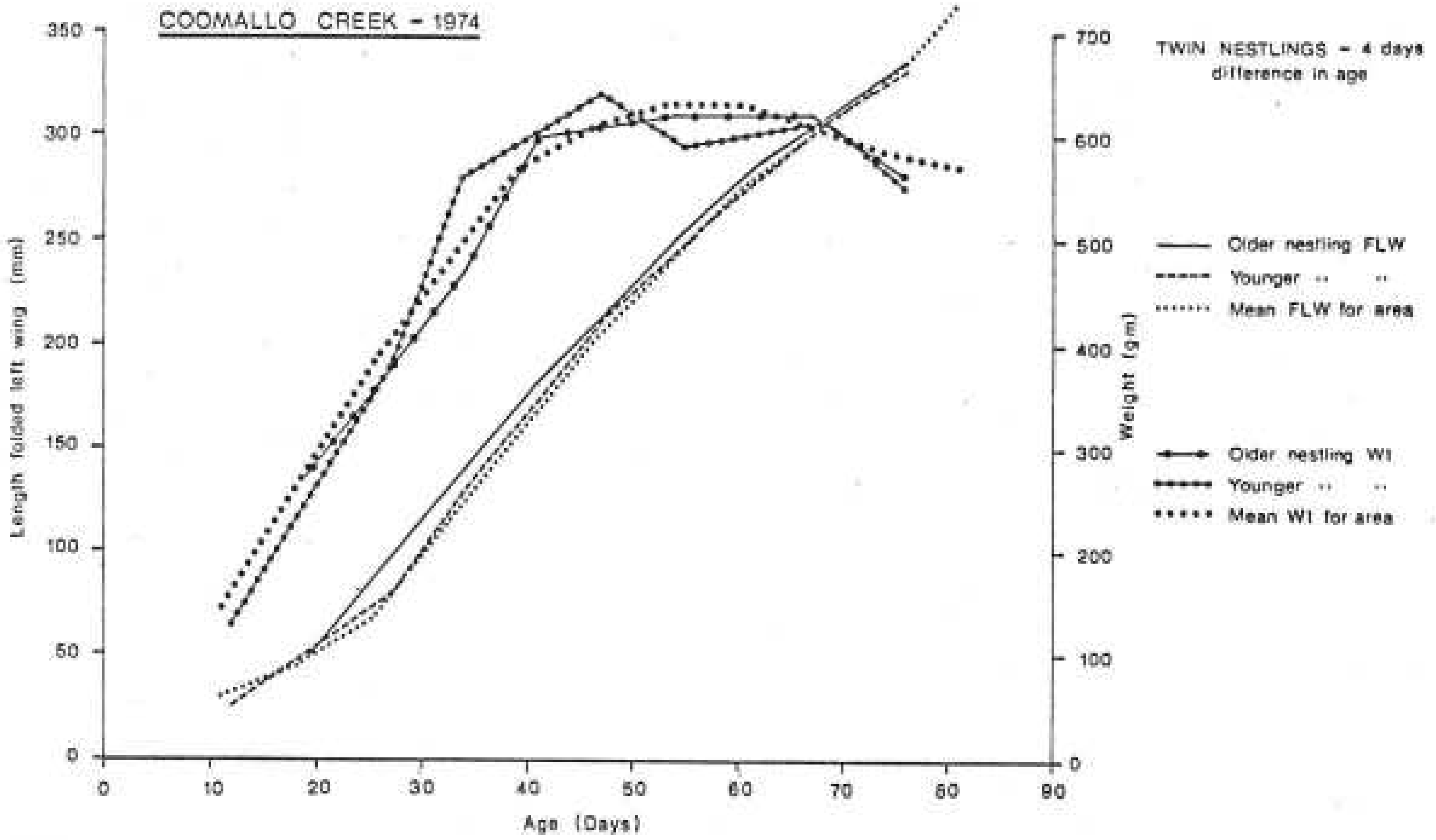

Figure 52. Coomallo Creek 1974. Growth curves for weight and length of folded left wing of twins from nest 150.

length of folded left wing between twins or the normal curve for the area. This is also true of weight in two cases but in the third where there was an age difference of nine days, the younger one was considerably lighter than its twin at the same age. It did fledge at the same weight as its twin (480 grams) but both were well below normal fledging weight (590 grams) for the area.

In those cases where there was an age difference of several days between the twins the older nestling fledged first but the adults returned to feed the younger one until it fledged also. In one case, however, once the older nestling fledged the adults abandoned the younger one and it starved to death.

There were no cases of twins fledging at Manmanning during the period of the study.

5.6.2.9 Growth curves for nestlings of individual females.

(i) Coomallo Creek. The growth curves of weight and length of folded left wing for the nestlings of one female from Coomallo Creek in three successive seasons are shown in Figure 53. This female is representative of 23 other females for whose nestlings similar curves could be drawn. The growth curves figured show little difference between the individuals.

(ii) Manmanning. The female from Manmanning whose nestling's growth curves are shown in Figure 54 is selected from a total of seven females and once again is representative. Growth curves for length of folded left wing show some variation from year to year but

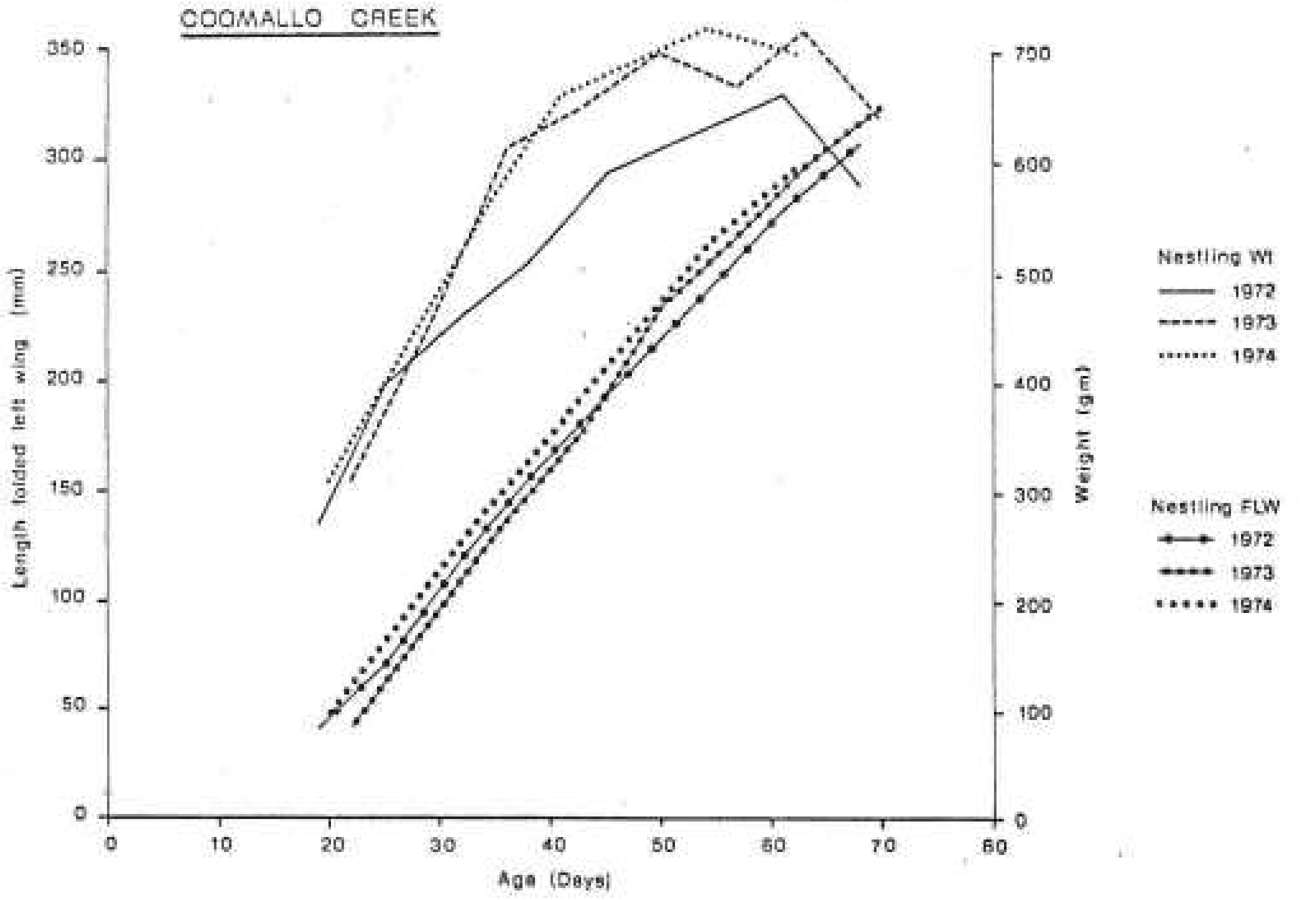

Figure 53. Coomallo Creek. Growth curves for weight and length of folded left wing for nestlings of female AN over three successive seasons.

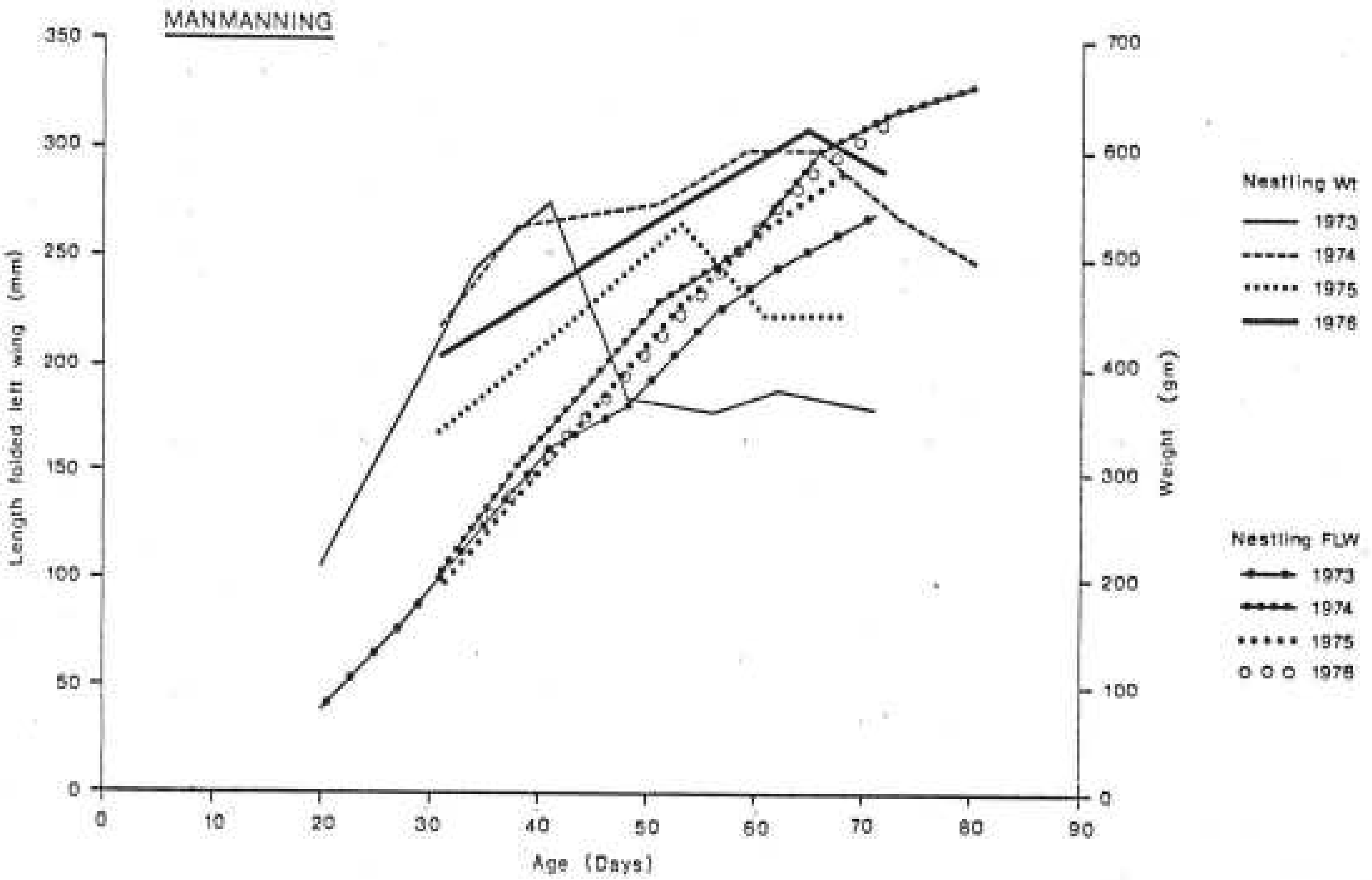

Figure 54. Manmanning. Growth curves for weight and length of folded left wing for nestlings of female OF over four successive seasons.

the weight growth curves show a great variation with vast differences in fledging weight, ranging from 360 to 580 grams.

5.6.3 Productivity. Productivity or nesting success, expressed as a percentage of total nests (in which eggs were laid) that fledged young is shown for Coomallo Creek and Manmanning for each year 1970-76 in Table 39. There were significant differences in success between years at Coomallo Creek with 1970 being most successful with 86 per cent of nests fledging young and 1971 being least successful with 56 per cent. Based on nesting success, several years can be grouped together and these groups are:-

(a)	1970:	85 per cent
(b)	1974, 1976:	71-76 per cent
(c)	1971, 1972, 1973, 1975:	56-61 per cent.

The overall success at Coomallo Creek was 65 per cent.

At Manmanning there was no significant difference in nesting success between years but when grouped into similar years based on nesting success, there were significant differences in success between these groups ($x^2_2 = 7.04$ $0.05 > P > 0.02$). The groups are:-

(a)	1971, 1976:	48-50 per cent
(b)	1970, 1974, 1975:	38-42 per cent
(c)	1972, 1973:	7-25 per cent.

The data for these groups are shown on Table 39. The overall nesting success was 35 per cent or just over half that at Coomallo Creek.

TABLE 39

Nesting success : Coomallo Creek and Manmanning

	1970	1971	1972	1973	1974	1975	1976	Total
MANMANNING								
No. of nests that fledged young	7	11	1	4	5	5	3	36
Total No. of nests	18	23	14	16	13	12	6	102
% success	39	48	7	25	38	42	50	35
COOMALLO CREEK								
No. of nests that fledged young	25	36	45	45	59	53	49	312
Total No. of nests	29	64	74	77	78	91	69	482
% success	86	56	61	58	76	58	71	65

Comparison between years in nesting success:

Manmanning $X^2_6 = 8.123$ $.30 > P > .20$ NS

Coomallo Creek $X^2_6 = 16.646$ $.02 > P > .01$ Sig.

Comparison between areas (1970-76): $X^2_1 = 8.77$ $0.01 > P > 0.001$

Significant difference between areas.

In 1970 at Tarwonga, 47% of 15 nests were successful and at Moornaming, 61% of 18 nests were successful.

Tarwonga suffered from human predation which lowered its nesting success but the results otherwise resemble the Coomallo Creek nesting success figures.

5.7 Immatures. After leaving the nest hollow the immature bird remains with its parents until they return to the breeding area at the start of the following breeding season.

5.7.1 Development of the colouring of the maxilla and cheek patch. The colouring of the maxilla of nestlings varies from the bone colouring of adult females through varying stages of grey to the black colouring of adult males. The cheek patch also varies from large and clear like the adult females down to small and dirty in colouring like the adult males. There is no size difference between sexes in adults but colouring is indicative of sex; the available data on colouring of nestlings and their subsequent changes after fledging were examined to see if nestling colouring is a reliable indicator of sex.

With this aim in mind, the data for eighteen nestlings that have been seen several years after they left the nest and whose sex is now known, were examined. These comprised eleven females and seven males, one of which was reared in captivity at Helena Valley and was five years old in November 1976.

The captive male had a black bill and a small dirty white cheek patch as it left the nest hollow, but very soon lost the colouring in its bill and it became bone coloured like the adult females. During the third year its bill progressively darkened and by the end of that year the bird's bill was black and its eye ring was pink. The bird then resembled an adult male. During this whole period the cheek patch stayed small in size as in the adult males.

Looking at the colouring of the other six males as nestlings, all had small cheek patches of varying colours graded through dirty white, white to dirty yellow. The bill colours ranged from bone with grey stripes through to black.

Immature females have bone bills and large cheek patches and resemble adult females. Examination of the colouring of the 11 females as nestlings, showed that all had medium or large sized cheek patches and colouring was white to yellow. Bill colouring ranged from bone coloured through to grey black.

Using cheek patch size as the criteria for sexing nestlings the Coomallo Creek nestling data for 1970 to 1974 were examined. These years had complete measurements and descriptions of nestlings each time the nest hollows were visited. The sexes of fledged young based on this criteria are shown on Table 40 and there was no departure from a 1:1 sex ratio.

5.7.2 <u>Age at first breeding</u>. By the end of 1976 only two known age females had bred for the first time. Both were at Coomallo Creek and one was four years old when she first bred and had bred for three seasons by 1976: the first two times successfully, the third time unsuccessfully. The other female was five years old when she bred first and she also bred successfully on this first occasion.

TABLE 40

Coomallo Creek : Sex of fledged nestlings (1970-74)

	♂♂	♀♀	Total
1970	10	16	26
1971	17	20	37
1972	26	23	49
1973	28	19	47
1974	24	31	55
TOTALS	105	109	214

Both birds had originally fledged from Coomallo Creek but neither nested in or near the hollow they originally fledged from.

No known age males had returned to breed in the study area by the end of 1978.

5.8 Discussion.

5.8.1 Distribution of nests. Throughout its breeding range, the White-tailed Black Cockatoo will nest in any eucalypt which has a hollow of a suitable size. The distribution of large trees along the coastal heathland is such that areas like Coomallo Creek are 'islands of nest sites' scattered throughout a heathland that is otherwise barren of woodland. The nearest patch of trees to Coomallo Creek is at Mt. Leseur, 28 kilometres to the west. The concentration of nesting birds at Coomallo Creek was different from the nesting distribution found in continuous woodland. For example, at Tarwonga where the study area was part of a large tract of State Forest, nests were all widely separated. It is only in regions where nest sites are restricted to particular areas for various reasons that the nesting birds appeared to be colonial. Parts of the wheat belt of Western Australia have nest sites restricted to standing trees around farmhouses or in uncleared reserves with very little available elsewhere. In the past nest sites were probably more uniformly distributed.

On first appearance with only about 40 per cent of available nest sites being occupied in any one season, it does not seem that the availability of nest sites could be limiting the population in any way, but considering those birds that laid at the same time or within a week of each other the birds were spaced through the breeding areas.

This was most likely to be as a result of interactions with other birds selecting and preparing their nests (see section 9.7.2.1) and that as a consequence of this, areas of timber were not available to some birds until the ones preparing their nest hollows in those areas were incubating and out of the way. Once this has happened, the area is accessible to other females and they may then nest nearby. In extreme cases females have nested in different hollows in the same tree and in every case the nests are staggered in time.

At Coomallo Creek, egg-laying takes places over about 12 weeks and is spread over that period without any clearly defined peaks. This spread may be as a result of the interaction between females during nest hollow selection and preparation. As a consequence of this behaviour, hollow availability may be a limiting factor as suggested by Haartman (1957). Increasing the number of hollows within the area would not allow the population to increase unless there were no hollows to start with or there was an increase in the length of the breeding season. The fact that the breeding season starts and finishes at about the same time each year indicates that it is probably at its limit now, so the only way to increase the population would be to increase the total area over which hollows are available. This would be true only if food was not limiting the population.

5.8.2 Laying season. The laying season has been taken as the period of egg-laying and Moreau (1964) states that most birds lay eggs during only a few weeks and months of the year in any given locality and that this period is strictly determined by natural selection. He further states that in nearly all environments for any given species of bird, one part of the year is more favourable than the rest of the year.

Two sets of factors operate on birds and through natural selection, determine the breeding season: 'the ultimate factors', good nest sites, etc. and the 'proximate factors' which function as signals telling of the approach of a suitable season. These factors are the changes in the birds environment which affect the physiological changes within the bird to stimulate or retard breeding.

There have been a number of reviews on laying seasons and the factors that influence them (Marshall, 1961; Lofts and Murton, 1968; Perrins, 1970). Marshall (loc. cit.) states 'no single overall factor (such as day length) is responsible for the timing of avian egg-laying. The laying season is kept in step with the sun essentially by the external factors that influence the female exteroceptor organs and ultimately permit nidification and ovulation on the habitual breeding ground.'

In the south-west of Western Australia, the climate is regular with a well defined wet period in the middle of the calendar year which coincides with the coldest period and also the period of minimum day length. This regularity of climate is reflected in the regularity of the laying season of the White-tailed Black Cockatoo. At both Coomallo Creek and Manmanning, laying commenced only two weeks either side of a mean date although Manmanning birds started on average a month after Coomallo Creek birds.

Coomallo Creek birds tended to be local in their movements during the non-breeding season and were usually found within 50 kilometres of their breeding area, whereas Manmanning birds moved and spent their non-breeding season nearly 200 kilometres away on the coast north of Perth (see section 7). Both populations were, therefore, subjected to similar climatic influences and the sort of factors that operate on the birds induce movement to the breeding areas at about the same time. Manmanning birds have further to go to return to their area and this may be partly the reason for the difference in starting dates.

In addition it appears likely that females increased in weight either prior to egg-laying or during incubation as shown by Coomallo Creek females who were four per cent heavier than females collected outside the breeding areas. This increase was most likely to take place between the time the birds were returning to the breeding areas and the time eggs were laid, at which time the female was completely dependent on the male. Perrins (1970) suggests that birds lay when food has become sufficiently abundant for each female to find enough food to lay without risk to itself. The limited data on Manmanning females indicates that they do not differ from the non-breeding population norm because they have either not increased in weight or because they have lost what increase they gained.

At Manmanning the modification to daily routine when some females who are incubating go out and forage, together with reduced nestling growth rates, indicates that the Manmanning areas may be short of cockatoo food. This limitation may affect the start of the laying season as it may take longer for the females to establish their energy reserves than it does for Coomallo Creek birds.

One of the advantages of breeding after the coldest and wettest period of the year is that foraging time increases as day length increases and potentially nearly all of the day except for commuting time is available to the male to forage during the period when his commitment is greatest i.e. feeding a female who is incubating or brooding a nestling. If food is limited, then this foraging time is important and it is advantageous to have as much useful time as possible. As the weather gets warmer, the birds do not forage in the hottest period of the day and at this time both parents are foraging so the task of feeding the nestling is borne by both. During the very hot part of the breeding season in late November and into December, the birds are often only able to forage in the early morning and late evening, the remainder of the time being spent sitting in shade trying to keep cool.

5.8.3 Clutch size. Lack (1954) considered that the clutch size of each species of bird under the influence of natural selection has been adapted to correspond with the largest number of young for which parents can, on average, provide enough food. He subsequently showed (Lack 1968) that nearly all offshore feeding seabirds have clutches of one, whereas nearly all of the inshore feeders have clutches of two or three eggs. He suggested that the offshore feeders have a less reliable food supply and that in response they raise smaller broods and have evolved smaller clutches than the inshore feeders.

Although the White-tailed Black Cockatoo normally lays two eggs, the second nestling usually dies within 48 hours of hatching and at Coomallo Creek the second nestling survived more than three days in only eleven out of 400 nests (i.e. 2.7%). There is a similar situation in White Boobies (*Sula dactylatra*) and Brown Boobies (*S. leucogaster*) reported by Dorward (1962) where more than one chick is very rarely raised from the two eggs. Dorward suggests that in these species the chick was ejected from the nest, not by the adults, but by the efforts of the larger chick. He thought that the larger one could hold up its head and push with its feet while the younger one could not and it forced the younger one out of the way and so got most of the food. Nelson (1967) discussing the White Booby regards this as sibling murder and describes how a six day old chick attacked its newly hatched companion and maintains that such attacks are undoubtedly responsible for the death of the smaller birds.

The normal response in very small White-tailed Black Cockatoos to the presence of something entering the nest hollow is to beg insistently. The action of the inspection light dropping into the nest hollow was usually enough to elicit this response. On several occasions the larger nestling lunged at the smaller one, knocking it over as it commenced begging. This may have been an attempt to put the smaller one at a disadvantage as far as receiving food was concerned. In one case involving nestlings that were several weeks old, the older nestling had bitten the smaller one on the leg, badly lacerating it. The difference in hatching dates may result in quite large size differences and the larger one may take up the most advantageous position in the hollow and get most of the food while the smaller nestling gets less and starves. This has been found in the Jackdaw (Corvus monedula) (Lockie, 1955) and the Heron (Ardea cinera) (Owen, 1955) where the smallest young get an unduly small proportion of the food because they cannot compete with their larger siblings.

In view of the fact that the second nestling usually dies within 48 hours after hatching, it is probably reasonable to assume that the actions of the older nestling ensure that it does not get sufficient food and starves.

Dorward (loc. cit.) suggested that the extra egg might serve as insurance against loss of one during incubation and in the White-tailed Black Cockatoo in several cases the first egg has failed and the second has given rise to the fledged young. The extra egg does occasionally produce an extra chick and so this will favour the retention of the habit in the species. In addition, clutch size being a hereditory factor, the two-egg clutches will still be favoured because they have a higher hatching success than single-egg clutches. White-tailed Black Cockatoo eggs are relatively small and the physiological effort involved in producing the extra egg is probably not uneconomic and the cost of producing the egg may be worth the insurance it provides.

Nest success during incubation and brooding depends to a large extent on the male's ability to supply enough food for his needs as well as his mate's. Although the female is dependent on the male, she will forage for herself if the male is not supplying enough for her needs, as has happened at Manmanning. This dependence of the female on the male is taken to its extreme in Hornbills (Kemp, 1970) where the female is sealed into the nest hollow leaving a small hole through which she is fed.

5.8.4 Productivity. At Coomallo Creek there was a tendency for clutch size to be reduced late in the laying season and fledging success to drop also. Klomp (1970) said that many birds breeding for the first time tend to have a slightly smaller clutch and that in general they start laying slightly later than older birds. This may be the case in the White-tailed Black Cockatoo with the older more experienced birds breeding earlier, tending to use the same hollow as they used previously and laying more two-egg clutches with the less experienced birds breeding later and laying fewer two-egg clutches.

The advantage of breeding earlier is that there is a better chance of taking up a known hollow and birds that breed in the same hollow are more successful than those that do not. In addition, the earlier the bird breeds, the less chance it will have of running up against a foraging time limitation in the latter part of the breeding season when it is much hotter. This is shown clearly at Manmanning where it is usually only the early breeding birds who are successful in fledging young.

This difference between Coomallo Creek and Manmanning is also shown in rates of growth of nestling weight and length of folded left wing. At Coomallo Creek there were no differences in the rate of growth of nestling weight between years yet at Manmanning there were wide fluctuations in growth curves for weight of individual nestlings and those that had rates of growth approaching the normal for Coomallo Creek nestlings were all laid amongst the first nests in each season.

Nestling weight is a better indicator of nestling condition for comparing the two areas as the length of folded left wing does not vary as quickly in response to food shortage as weight does. Nelson (1964) states that variations in food intake at time of intensive feather development and high metabolic requirements will quickly be reflected in the weights of chicks. The growth curve for length of folded left wing shows the usual form even during periods when weight is drastically below normal although it has a reduced rate of growth. By maintaining flight feather growth as high as possible during periods of reduced weight gain, it is possible for nestlings to fledge at around the normal time even though their weight is well below normal fledging weight. For example, at the lowest end of the range for Manmanning, nestlings of the 10-11 week age class have a length of folded left wing of 70 per cent of adult size but a weight of only 55 per cent. At Coomallo Creek the figures are 80 per cent and 78 per cent. Although the chances of a nestling surviving after fledging well below normal weight are probably low, they are probably much better than remaining in the hollow and depending on adults foraging in an area which has a poor food supply. Once out of the hollow, the adults can lead the fledgling to a more reliable food source provided it has the energy and necessary flight capabilities to get there. Once near a more reliable food source with no commuting time required then the fledgling's chances of survival would be much enhanced.

Coomallo Creek weight curves for nestlings in different seasons from the same female show little variation whereas Manmanning nestlings show large variation indicating it is not the experience of the breeding female that is responsible for this variation but that there is some shortage of food in the area which is not the case at

Coomallo Creek. In hot weather when foraging times are reduced there does not appear to be enough time to gather sufficient food for the nestlings and this is shown by the reduced weight gains, and in some areas, weight losses in periods of hot weather. At Manmanning the years with the worst breeding success, i.e. 1972 and 1973, were the years that started latest. Coomallo Creek adults are able to find enough food even during hot weather to ensure that nestling rates of growth remain relatively constant in the area. The fact that incubating females at Manmanning are seen out foraging while Coomallo Creek birds are not, also points to a food shortage in the area.

Connected with this food shortage there are large differences in breeding success between the two areas with Coomallo Creek having a success rate of 65 per cent overall which is nearly twice that of Manmanning at 35 per cent. As shown in the section on eggs (section 5.4), both areas have similar hatching success in both one and two-egg clutches but a great difference in success between hatching and fledging and the difference in food supplies is almost certainly responsible for these differences.

5.8.5 Twins. It is possible for one adult successfully to maintain and fledge its nestling after the loss of its mate. This was seen at Coomallo Creek several times when either one of the adults disappeared and the remaining adult went on to fledge the single young within the normal size range. Therefore, two adults should be able to fledge twins and the growth curves for those twins at Coomallo Creek for which sufficient data were available showed that it is possible in some seasons to provide enough food to allow both nestlings to develop normally and fledge within the normal period. Of the eleven nests at Coomallo Creek where the second nestling survived more than three days, eight (i.e. 2.6% of two-egg clutches for area) have successfully fledged both young. It was also those years with higher nesting success and clutch size which had successful double fledgings. The years 1971 and 1973 had the lowest success and clutch size and there were no double fledgings in those years (Figure 30). At Manmanning, not one of the 94 nests had successfully fledged two young and the longest a second nestling had survived was three to four weeks. At Tarwonga in 1970, there was one nest with twins in it and they were successfully reared until the larger one was nine to ten weeks old when the nest was chopped into and the contents stolen. Both nestlings were within the normal weight range and would probably have fledged.

It seems that if a second nestling survives the first three days there is a good chance that it will successfully fledge (over 70 per cent of these did so at Coomallo Creek), provided there is sufficient food for both.

6. Food

6.1 Introduction. There is very little detailed published information on the food of the White-tailed Black Cockatoo. Alexander (1916) noted that in the Bremer Bay area they found their food in the open country on low shrubs or on the ground. Carnaby (1933) stated that in the Lake Grace district the short-billed White-tailed Black Cockatoo lived on the open sandplain and mallee country and its food consisted of large hard nuts. Serventy (1948) recorded that the birds were attracted to the Forests Department pine plantations where they ate the pine seed and Perry (1948) gave an excellent account of the way the birds attacked the pine cones and extracted the seed. Carnaby (1948) observed that the birds fed on the large hard nuts of *Banksia* and *Hakea*, and Sedgwick and Sedgwick (1950) saw the birds feeding in *Banksia* near Lake Wheatfield, north of Esperance. The birds were recorded as feeding on *Pinus spp*. at Wooroloo (Sedgwick 1955) and Robinson (1960) gave a very good account of the flowering and fruiting cycle of the marri and pointed out that the White-tailed Black Cockatoo consumed large quantities of nectar from the marri blossom. He went on to say that as the marri fruit was procurable in some form throughout the year, it was of great value to the birds who fed on it. Robinson also illustrated the way various birds, including the White-tailed Black Cockatoo, extracted the seed from immature marri fruit and mentioned that they also exploited new foods and referred to apple and pear orchards as well as pine plantations. Sedgwick (1964) recorded a flock feeding on *Dryandra* heads near Bluff Knoll in the Stirling Ranges while Robinson (1965) noted them feeding on the pupae of a braconid wasp which inhabits the galls on *Banksia attenuata*. He also said that the birds were noted for the way they tear off the bark of dead and dying trees to get the larvae of a longicorn beetle (Cerambycidae). Serventy and Whittell

(1967) stated that the birds fed on the blossom and fruits of gum trees; grubs under the bark of dead trees, particularly jarrah; and inland on the hard fruits of *Hakea crassifolia*. Forshaw (1969) discussed both the Yellow-tailed Black Cockatoo and the White-tailed Black Cockatoo and said that they were particularly fond of the seeds of *Eucalyptus*, *Acacia*, *Hakea*, *Banksia* and the introduced *Pinus* trees and that the White-tailed Black Cockatoo has largely forsaken an insectivorous diet in favour of seeds.

De Rebeira and de Rebeira (1977) recorded the birds feeding on flowers of *Dryandra* in sandplain country west of the Wongan Hills. Serventy and Whittell (1976) summarised the published information and said that when the gum trees were in flower, the White-tailed Black Cockatoos consumed large quantities of nectar and when in fruit, they ate the seed. At Boyup Brook in September and October they fed on the wild geranium and in jarrah areas they fed on grubs found under the bark of dead trees. Serventy and Whittell reiterated their earlier statement that in the drier inland they fed on the fruits of *Hakea crassifolia* and they occasioned great loss to apple orchards and as a result were declared vermin in some districts.

All of the above information except Carnaby (1933, 1948) does not refer specifically to either the long-billed or short-billed White-tailed Black Cockatoo but to both. Saunders (1974c) gave the only specific account of the food eaten by both forms and stated that marri seeds and insect larvae were found to be important food to the long-billed birds whilst seeds of *Pinus*, *Dryandra* and *Hakea* were found to be important to the short-bills.

As pointed out in the Methods section, the only crop specimens collected in the breeding areas were from birds found dead, both adults and nestlings. The numbers of these were small and so the information collected from observations on feeding birds have been used in the following sections. One feeding observation was made each time a bird (or group of birds) were seen feeding on a particular item. For example, if seven birds were seen feeding on items A and B then that would constitute one observation each for A and B.

6.2 Coomallo Creek. The list of species that were exploited by the White-tailed Black Cockatoo for food at Coomallo Creek is shown in Table 41. The only introduced species used by the birds in this area were the seeds of the wild geranium (*Erodium spp.*) which occurred in only small patches at the south end of the study area on cleared farmland. Over 90 per cent of feeding observations were made on native vegetation and of these the single most important were seeds of *Hakea lissocarpha* of which were were extensive stands throughout the study area. It was common near stands of woodland and the birds appeared to favour these areas as they could sit in the trees when not feeding, then fly down to feed, returning to the trees after feeding.

The birds were also seen to feed on flowers as well as the seeds of *Banksia*, *Dryandra* and *Lambertia multiflora*.

Some plant species were parasitised by insects whose larvae developed in the flowers or in the stems. Some of these larvae were found in nestling crops sufficiently often to suggest deliberate collection.

6.3 Manmanning. The species that were exploited by the White-tailed Black Cockatoo at Manmanning are shown on Table 42. A black

TABLE 41

Coomallo Creek : Species used by White-tailed Black Cockatoos for food

	Group Observations*	Crop Contents+
a) PLANT SPECIES		
Banksia attenuata	1	
B. menziesii	1	
Dryandra fraseri	3	
D. sessilis	2	1
D. speciosa	1	
Erodium spp.	7	1
Hakea auriculata	1	
H. conchifolia	1	
H. gilbertii		7
H. incrassata	1	8
H. lissocarpha	51	
H. obliqua	1	
H. prostrata		4
H. scoparia	1	
H. sulcata	3	
H. undulata	4	4
Lambertia multiflora	4	
b) ANIMAL SPECIES		
Insect larvae (unidentified)		2
NO. OF OBSERVATIONS:	82	-
NO. OF CROP SPECIMENS:	-	12

* Number of times birds seen feeding on this item. (One observation is taken each time any number of birds from one up is seen feeding on a food item).

\+ Numbers of crops that contained this food item.

TABLE 42

Manmanning : Species used by
White-tailed Black Cockatoos for food

	Group Observations*	Crop Contents[+]
a) PLANT SPECIES		
Casuarina spp.	2	
Dryandra affincircioides	2	
Erodium spp.	48	4
Grevillea apiciloba	53	
G. armigera	4	
G. paniculata	2	7
G. paradoxa	1	
G. petrophiloides	1	
Hakea circumalata	1	
H. falcata	3	
H. incrassata		3
H. multilineata	2	2
H. scoparia	18	
H. sulcata	7	
Isopogon scabriusculus	1	
b) ANIMAL SPECIES		
Insect larvae:		
Family Cerambycidae		1
Family Pyralidae		1
NO. OF OBSERVATIONS:	145	-
NO. OF CROP SPECIMENS	-	12

* Number of times birds seen feeding on this item.

[+] Number of crops that contained this food item.

'toothbrush' flowered shrub, Grevillea apiciloba, was the most commonly eaten plant. It grew in patches that were left uncleared and the birds fed extensively on the flowers and seeds.

Hakea scoparia was the next most important native item accounting for 12 per cent of observations with the other 12 native species making up 18 per cent of the observations.

In this area Erodium spp. made up 33 per cent of the feeding observations. There were extensive areas of Erodium at Manmanning compared with native vegetation but it was only available over a very restricted period. The birds only fed on it just prior to ripening when it was still green through until it just turned brown. For example, birds were seen feeding on Erodium in 1973 from mid-October to mid-November and in 1974 from mid-October to the first week in November. Once the Erodium seed was ripe and had browned off, the birds no longer ate it and thereafter only native vegetation was eaten. It was not unusual to find almost all of the breeding birds, except for those females who were incubating eggs, feeding as one group on a patch of Erodium. For example on 18 October, 1974 all of the birds known to be nesting in the area, except for females incubating, were in one group feeding on Erodium about two kilometres from the centre of the main breeding reserve.

In contrast G. apiciloba occurred in thin ribbons along railway and road verges which in some cases were only one shrub wide (Figure 5). This difference in availability of these two food sources was shown in that the average group size of birds seen feeding on Erodium was 12.5 (S.E. 1.2) (48 observations) which is more than double that seen on G. apiciloba at 5.1 (S.E. 0.5) (53 observations) (significant difference between means 0.001 > P).

The overall importance of insect larvae in the diet of the nestlings was not known but flowers of Dryandra affincircioides in one reserve in the study area appeared to be parasitised by larvae of the family Pyralidae. That parents actively foraged for these was shown by one nestling which appeared to have a crop full of these larvae.

6.4 Comparison between Coomallo Creek and Manmanning At no time were the birds found eating any cereal crop or other exotic species (apart from Erodium) in either area. There were no Pinus or almond trees in either area, and these were attacked throughout the range of the short-billed White-tailed Black Cockatoo.

Although the vegetation in the two areas was slightly different, native species formed the basis of the diet and only at Manmanning did any exotic species (Erodium) appear to be important, but this was available for only three to six weeks.

In both areas the birds depend on native heathland species and at Coomallo Creek there were extensive areas of heathland contiguous with the woodland areas. The birds were able to feed close to their nesting area and the average distance individuals were seen from their nests while foraging was 1.4 (S.E. 0.1; range 0-7.1) kilometres (147 observations).

At Coomallo Creek the size of groups of birds seen feeding together have not changed during the period from 1971 to 1976 and averaged 15 (15.1 S.E. 1.3) birds (196 observations). The study area had a breeding population in excess of 80 pairs and the birds fed in small groups close to their nest sites. In this area large groups (of about 100 birds) were seen from the start of the breeding season to the time that eggs were laid and then the groups broke up into smaller groups. In hot weather when the birds moved to watering points, larger numbers were seen as the feeding groups flew in from different directions and congregated in the trees prior to drinking.

At Manmanning there was little uncleared native vegetation and even less of this was contiguous with the woodland in which the birds nested. In this area the average group size was eight (8.1 S.E. 0.5) (177 observations) and was just over half the size of the average Coomallo Creek feeding group size. At Manmanning this represented about 25 per cent of the breeding population in the area whereas at Coomallo Creek the average group size represented 9 per cent or less.

The average distance feeding birds have been seen from their nests at Manmanning was 2.5 km (S.E. 0.2; range 0.6-12.1) (153 observations) and was significantly greater than at Coomallo Creek ($P < 0.001$; $d = 5.83$, $0.001 > P$, 260 degrees of freedom).

At Manmanning the dependence on road and railway verges showed up clearly. The railway verge to the north-east of the main reserve was very heavily exploited and here the birds grazed on native vegetation. To the west of the reserve is an area where the birds grazed repeatedly on *Erodium* when it was available and for the remainder the birds foraged over large areas.

A number of road verges and sections of the railway verges were devoid of native vegetation, for example, the road leading west from the centre of the reserve. Except where Erodium was available, the nearest available food to the west of the reserve was at the T-junction four kilometres away. In order to find that food the birds would have had to search the area between. Having found and exploited that food they would then have had to search for the next source. In some cases there were continuous verges that led to other available food as shown at the south-east corner of Manmanning townsite where there was a thinly vegetated verge along the main access road. The birds were channelled along it until the food was exhausted.

The facts that females were seen out foraging while they were incubating, that females ceased brooding during the day earlier than at Coomallo Creek and that nestlings which hatched later in the season had very little chance of fledging, point to a food shortage at Manmanning which did not occur at Coomallo Creek.

One substantial source of food at Manmanning was not exploited. About four to five kilometres south of the main reserve was a flora and fauna reserve of 340 hectares, mainly sandplain heath with a considerable amount of food in it, yet the birds were not seen there. Possibly because there was no continuous corridor of vegetation leading to it from the main reserve, the birds might not have discovered it.

Only the Erodium crop at Manmanning was sufficiently concentrated for the entire population to exploit it at once. The rest of the time the birds were forced to forage widely. There seemed to be some ambient temperature above which the birds became uncomfortable and sat in the shade in an attempt to keep cool. As the hot weather approached so the time spent sitting increased and foraging time was reduced at a time when the nestling's needs were greatest. As a consequence insufficient food was available at Manmanning for the population to breed successfully.

6.5 Food during the non-breeding season. The birds only remained in the breeding areas from July/August until December/January (Saunders 1974a). During the remainder of the year they foraged in other areas. A detailed account of movements and group sizes during different periods is given in a following section (Section 7) but an account of the food the birds eat during the non-breeding season is important to understanding their ecology.

6.5.1 Coomallo Creek birds. The Coomallo Creek population spent the non-breeding season in the area between the Hill River (into which the Coomallo Creek drained) and the Arrowsmith River south of Dongara. Observations of White-tailed Black Cockatoo groups seen feeding in this area during the period of the study between January and July were made and those species exploited by the birds are listed on Table 43. The most important species was marri and its seed accounted for 48 per cent of the observations.

Marri occurred in narrow strips along the major watercourses as far north as Stockyard Gully, 23 kilometres south-west of Eneabba (see Figure 55). During the drier part of the year the birds concentrated on these watercourses because they were among the few spots where water was available.

TABLE 43

Coomallo Creek birds : Species used by White-tailed Black Cockatoos for food between Hill and Arrowsmith Rivers

Plant species	Group observations
Banksia ashbyi	1
B. attenuata	9
B. grandis	3
B. menziesii	4
Dryandra nivea	1
D. sessilis	3
Eucalyptus calophylla (marri)	41
E. todtiana	3
Hakea lissocarpha	4
H. obliqua	2
H. prostrata	1
H. ruscifolia	1
H. trifurcata	5
H. varia	1
Lambertia multiflora	1
Emex australis (double-gees)	1
Lupin seed	1
NO. OF OBSERVATIONS	82

The only exotic species that the birds were seen to feed on were seeds of double-gees (Emex australis) and lupins (Lupinus spp.) on a property on the Arrowsmith. There were still extensive tracts of uncleared sandplain heath around watering points throughout this area and food appeared to be adequate for the population.

6.5.2 Manmanning birds. The Manmanning birds spent the non-breeding season in the area between Perth and the Moore River on the coastal plain (Figure 55). Between 1970 and 1972, 169 White-tailed Black Cockatoo specimens were shot around Gnangara and Somerville Pine Plantations and 77 in Dale Forest near Mundaring in the period February to August. These samples were collected for an earlier evaluation of the taxonomic status of the birds and the results have been reported elsewhere (Saunders 1974b and 1974c). Somerville Pine Plantation was in the Perth metropolitan area and Dale Forest was an area of jarrah-marri forest on the Darling scarp which had large pine plantations interspersed in it. The crop contents from these specimens were removed and analysed. The list of species found in these crops is given on Table 44 as are those species that were seen to be eaten by birds in the area during the period of the study.

In addition to the pine plantations mentioned, there were extensive ones to the north-west of Gnangara to a point mid-way between Yanchep and the Moore River. In addition to these large plantations, there were several small trial plots scattered through the uncleared heathland.

The large build-up of birds in the pine plantations at the end of the breeding season has been noted elsewhere (Saunders 1974b)

TABLE 44

Species used by White-tailed Black Cockatoos for food between Perth and Moore River

	Group Observations	Gnangara/ Somerville	Dale Forest
a) PLANT SPECIES			
Banksia attenuata	1	31	3
B. grandis			3
B. verticillata	1		
Dryandra nivea	17		10
D. nobilis			3
D. praemorsa	3		
D. sessilis	1		5
Eucalyptus calophylla	7	1	10
E. marginata	2		2
E. redunca (blossom)	1		
Hakea auriculata	1		
H. cyclocarpa	1		1
H. gilberti			1
H. prostrata	6		4
H. undulata	2	1	14
H. varia	4		
H. trifurcata			7
Pinus spp.	20	165	52
b) ANIMAL SPECIES			
Insect larvae		5	
NO. OF OBSERVATIONS:	67	-	-
NO. OF CROP SPECIMENS:	-	169	77

and it is not surprising to find that in this area seeds from *Pinus spp.* were very important, even though the pines occurred in plantations surrounded by native forest. A concentrated source of seed was always available in plantations, but even in large ones the birds still foraged for native food and *Banksia attenuata*, which was common around Gnangara and Somerville during the period of the study, was an important food item.

Dryandra nivea, a prostrate plant, was very common through this area and its seeds and flowers were also important food as were the seeds and flowers of marri and the seeds of *Hakea undulata*.

Insect larvae did not appear to be important.

6.6 *Conclusions*. Both the Coomallo Creek and Manmanning populations relied on food collected from native vegetation throughout the year. The Coomallo Creek birds had sufficient food for both the breeding season and the non-breeding season but the Manmanning birds had inadequate food available in their breeding areas. Once they have left the breeding areas for the coast there was sufficient food available in uncleared native vegetation and exotic *Pinus* plantations.

7. Movements

7.1 Introduction. One of the first references to movements of the White-tailed Black Cockatoo was Leake's comment (in North, 1911) that the birds leave the Kellerberrin district in November and December 'for the coast'. Orton and Sandland (1913) noted that the birds were common in the Moora area but were absent during the summer from November to early December when they left for the sandplain country towards the coast, returning to Moora in flocks after the first rains. Le Souëf (1914) commented on group size in this area and said that "30 miles west of Moora we motored through a flock of 300 black cockatoos which flew along in front of the car for nearly a mile". Serventy (1937), writing of the Swan River district and Sedgwick (1940) of the Rockingham district, both mentioned a general northwards movement in autumn and southwards in spring, indicating that the movement of birds in this area was noticeable then. Serventy (1948) added that in the tuart belt north of Perth, flocks may be seen during most of the year and mentioned the large numbers that were attracted to the Forests Department pine plantations. Perry (1948) reported that the birds moved into the pine plantations around Perth in February and March and left in August and September. Saunders (1974b) reported the build-up of birds in Somerville, Gnangara and Mundaring pine plantations in January/February with a decrease starting in March/April in some plantations and ending in June in the large Gnangara plantation.

Davies (1966) used the records of a series of observers to explain the movements of the White-tailed Black Cockatoo population in the Albany-Kojonup area. He found that the birds moved to the south coast and thought that this was a post-breeding movement from the inland to the coast. He had limited data for the population north of Perth but he thought that there was a post-breeding movement to the west coast.

The following movement studies were based on the return of leg bands and wing tags and tag sightings of birds away from the breeding areas between January and July/August each season from 1972 to 1976.

7.2 Coomallo Creek population movements. The movements of birds from the Coomallo Creek breeding area are shown in Figure 55. These results are based on three tag returns and 718 sightings of 177 tagged individuals.

The longest movement was by an immature bird which fledged at the end of the 1975 breeding season and was seen near "Glenvar" homestead near Manmanning in company with four untagged birds a year later, in December, 1976. This bird was 154 kilometres from the breeding area. Observations have shown that after fledging, immature birds remained with their parents for up to eight months but that the parents returned to the breeding area without their offspring (section 9.7.2). The movements of these immature birds from that time until they breed for the first time are not known. Some known age individuals have been seen up to three years after fledging in summer groups containing Coomallo Creek breeding adults, so some must remain in the general area. The sighting of the bird at "Glenvar" suggests that others may wander over larger areas.

On Figure 55 the locations of places where tagged Coomallo Creek birds have been seen are plotted. The birds moved away from the breeding area in groups as they finished breeding and not 'en masse' after the last birds had finished. They did not gather at the same areas but collected in several different areas;

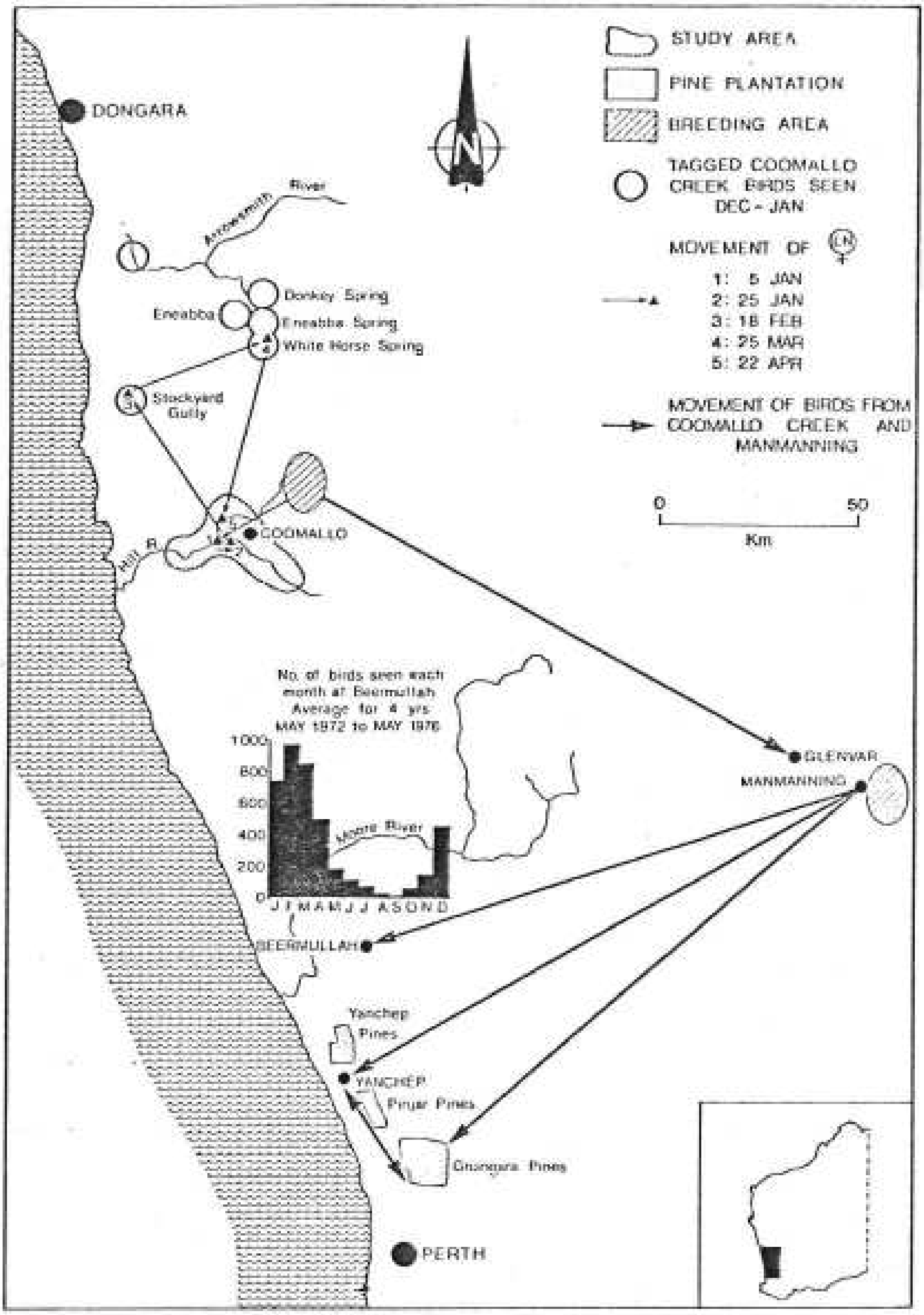

Figure 55. Movements of birds from Coomallo Creek and Manmanning.

for example, in early January 1975 there were still birds with young in the nests and at the same time there were 50 birds at Eneabba Spring and 290 on the Hill River, both groups containing birds from Coomallo Creek which had already finished breeding.

There were over 80 breeding pairs at Coomallo Creek with a total breeding success of 65 per cent and as a result a population of over 210 birds would have left the area by the end of the breeding season. The average group size seen between the Hill and Arrowsmith Rivers between December and the following June was 176 birds (number of groups seen = 52) ranging from ten to 400. Between 23 and 25 March 1977, there was a group of 300 birds along the Hill River, a group of 300 around Stockyard Gully and 150 around Whitehorse Spring. All three groups contained Coomallo Creek birds and the total number of birds was 750. Obviously these groups also comprised birds from several other breeding areas.

Between December 1976 and June 1977, the area between a point just south of the Hill River, north of the Arrowsmith and east of the breeding area was searched systematically for White-tailed Black Cockatoo groups and any seen were checked for tagged birds. Sixty-three per cent of the tagged females and 75 per cent of the tagged males that bred at Coomallo Creek in 1976 were seen during this period.

The area was characterised by large tracts of native heathland with an occasional natural spring surrounded by trees. At these points and in pools along the Hill and Arrowsmith Rivers there was permanent water available during the summer. In the very hot period from December through to the first heavy rains, the birds watered every day and congregated on these watering points and sheltered in the trees during the hot part of the day.

These groups were not static as observations showed that some individuals left one group at one location and joined another at some other location. The movements of one female, LN, are shown on Figure 55 and illustrate the movement within the area. Another female, QZ, was seen in a group of 300 on Hill River at 1700 hrs on 22 March and in a different group of 150 at Whitehorse Spring at 1000 hrs on 25 March, a distance of 45 kilometres in two days.

With the onset of the cooler weather and the rains in April or May, water became widely available and the birds were no longer restricted to the vicinity of permanent watering points and spread over a wide area.

7.3 Manmanning population movements. The movements of Manmanning birds are shown in Figure 55 and are based on one tag return and 61 observations made on 14 tagged individuals.

Once pairs had finished breeding they moved out of the area with others who had also finished and left those who had not. The birds moved to the south-west towards the coast. A bird shot at Beermullah had left Manmanning at the end of December/early January and was killed at the end of February. It was part of a large group of several hundred birds who had been in the area for several weeks. The area around Beermullah is sandplain heathland and low lying swampland with areas of marri and the occurrence of White-tailed Black Cockatoos in the area each month averaged over four years is shown on Figure 55. During the breeding season from July to November there were few birds in the area but numbers started to build up in December, reaching a peak in February.

Yanchep National Park was an area of uncleared heathland and woodland with Forests Department pine plantations to the north and south-east. Within the park there was a swamp with dead Banksia trees in which the White-tailed Black Cockatoos settled before drinking in the swamp. During 1975 a tower was set up with a hide on it and a series of watches were kept on the swamp at regular intervals from 1500 hrs to dark. If the birds were in the area then they usually drank at this point just before dusk and records were kept of total numbers of birds drinking and of tagged birds seen. The results of these hide observations are shown on Figure 56 and in January and February the total number of birds seen drinking built up to over 1000 birds and remained high until June when numbers dropped and remained low until the end of the breeding season.

Manmanning birds were first seen in the Yanchep area in mid-January and remained there until the end of August by which time some of the birds were already back at Manmanning starting to prepare nest hollows. The shortest period between being seen at Yanchep and then at Manmanning was 13 days.

By June 1977, 18 per cent of the total tagged females and 24 per cent of the males from Manmanning had been seen at some stage at Yanchep. Some birds, therefore, must have gone to other areas, e.g. Beermullah, for the entire non-breeding season.

There are some large pine plantations just north of Perth and large groups of cockatoos build up in them. Perry (1948) refers to

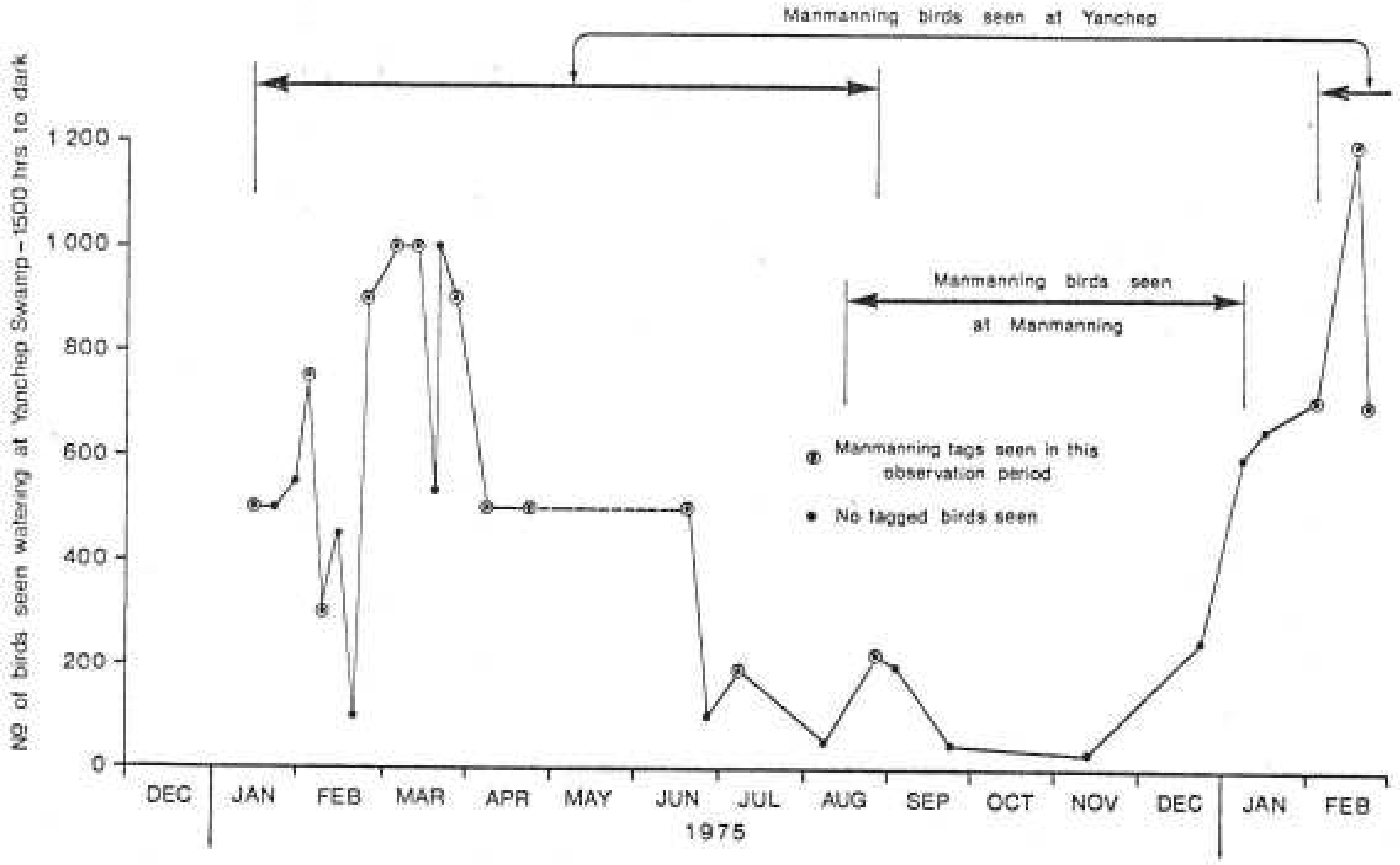

Figure 56. Number of birds seen drinking at Yanchep Swamp during observation made in 1975.

groups of 5000-6000 birds and I have seen groups of this size between January and April. There is an interchange of individuals between these different plantations and male OI, for example, was seen in Gnangara in a large group on the same day that other Manmanning birds were seen at Yanchep. About six weeks later, he was seen at Yanchep and then next seen at Manmanning at the start of the breeding season.

Immature birds in their first year have been seen with their parents at Yanchep and subsequently in their second year they have been seen in the Yanchep groups. Unfortunately there was no information on older immature birds, but it is probable that they wander nomadically in this area until they begin breeding.

7.4 Tarwonga population movements. The movements of birds from Tarwonga are based on three band returns. All three were immature birds and one was killed by a car while feeding on a road verge near Crossman, 60 kilometres north-west of Tarwonga only four to five weeks after fledging. The other two were shot while feeding in almond trees in backyards in Narrogin townsite (25 kilometres north-east) in a group of about 150 birds. One was shot in April, 16 months after it had fledged and the other in May when it was six months old.

Observations made by Narrogin residents show that the birds were common in the area from January to May/June and that they fed on marri and almonds in the area. Other birds moved away as shown by the Crossman bird. Between Perth and Crossman there were pine plantations at Gleneagle, 130 kilometres north-west of Tarwonga and groups of birds build up in that area.

The breeding area at Tarwonga was on the edge of extensive forest that stretched from Perth to Albany in which groups of birds wandered nomadically. The Crossman bird may have been part of one of these groups.

7.5 Discussion. The short-billed White-tailed Black Cockatoo nested throughout its range during the period July/August to December (section 5.2, Saunders 1974c). At the end of the breeding season there was a movement away from the breeding areas and groups from one area may split up and amalgamate with those from other areas to wander in search of food. The size of these groups depended mainly on available food and such areas as large pine plantations may support very large numbers over the non-breeding season and probably over most of the year in the case of immature birds that do not return to the breeding areas. Native food sources were not as concentrated and the birds remained there only as long as there was food available (Saunders 1974b).

Of the populations studied, information on movements was available from three and showed that there was a movement out of the breeding areas to regions of higher rainfall closer to the coast once breeding was completed.

At Coomallo Creek and the surrounding country where there were extensive uncleared areas, the birds were able to forage locally, joined by birds from other surrounding breeding areas.

At Manmanning, further from the coast, there was less food available and the birds underwent a definite migration from breeding areas to feeding areas and back each year. The large groups of birds around Perth were probably made up of many such breeding groups together with their non-breeding immature progeny.

It seemed that over the range of the short-bill, after the breeding season there was a movement towards the higher rainfall areas where there was more food available and in the northern populations this involved a move to the west coast and in the southern populations, a move to the south coast.

8. Population dynamics and mortality

8.1 Mortality factors.

The cause of death was known for 38 individuals. These causes can be divided into three categories: accidents, shooting and predation. The data for the 28 adults and 10 immatures from Coomallo Creek, Manmanning and Tarwonga are shown in Table 45. Only seven of these tag/band returns were from people not involved in the study which represents a return rate of less than 0.9 per cent.

8.1.1 Accident deaths

8.1.1.1 Hit by car.

When the birds were feeding close to a road, the noise of a car approaching often caused them to take flight. When taking off the birds flew away from their feeding site by the shortest route and if this happened to be the road side of a shrub then they may have flown into the path of the oncoming car.

Five of the eight birds that died accidentally were killed in collisions with cars. There was only one such death in the Coomallo Creek and Tarwonga populations, but there were three at Manmanning. Of these three, one female and a male were killed while feeding together. All three were killed on the Dowerin-Cadoux Road, which was sealed, narrow, straight and fringed with native shrubs, and cars frequently travelled at high speed along it.

As the birds at Manmanning often fed along road verges, this exposed them to this type of accident more frequently than

TABLE 45

Mortality

Cause of death	Coomallo Creek ♀	Coomallo Creek ♂	Coomallo Creek Imm.	Manmanning ♀	Manmanning ♂	Manmanning Imm.	Tarwonga ♀	Tarwonga ♂	Tarwonga Imm.	Total
ACCIDENT:										
Hit by car		1		2	1				1	5
Other (part of body caught in tree; drowned)	2		1							3
SHOOTING:	1			1					2	4
PREDATION:										
Taken by Wedge-tailed Eagle	15	2	6	3						26
TOTAL	18	3	7	6	1	-	-	-	3	38
No. of birds banded/ tagged in above 3 areas:	189	66	347	33	25	45	3	3	22	733

TOTAL BANDED/TAGGED : 804

the birds at the other study areas.

8.1.1.2 Other accidents. Two females at Coomallo Creek died because they got stuck somewhere in nesting hollows. One of them pushed her head through a fairly narrow opening while prospecting and could not get it out. The other was backing into her hollow and got her foot caught in a V-shaped groove on the inside of the hollow. She hung suspended and presumably starved to death. From the amount of chipping around the area where her foot was trapped, she had tried very hard to extricate herself. The small nestling in the hollow also starved as the female was blocking off the spout.

The only other accidental death was an immature bird from Coomallo Creek that drowned in a stock tank at Whitehorse Spring. When coming to drink, the birds usually landed on a perch nearby before flying down to land near the water source and walk up to it. Any object higher than the water source was used as a perch and it was not unusual to see them on fences, windmills, nearby trees or stock tanks. The water levels in stock tanks were usually too far down for the birds to drink from, but while perched on them, an occasional gust of wind may throw them off balance and topple them into the tank from which they cannot escape.

8.1.2 Shooting. The White-tailed Black Cockatoo was (and still is) protected throughout its range except in certain apple growing areas which were outside the range of the populations in this study. Four birds were shot but only one of these, the Coomallo Creek female, was shot in the breeding area. This loss was a direct result of the bird being tagged conspicuously because the person who shot the bird did so because he 'wanted to take a look at one of these tagged birds'.

The Manmanning bird was shot while feeding in marri trees in company with several hundred birds near a farm house. The noise and mess they created so upset the resident that he fired several shots into the foliage of the tree to scare the birds off. In doing so he killed several birds.

The Tarwonga birds were shot because they were raiding almond trees in backyards in the Narrogin townsite.

8.1.3 Predation. The only known predator of the White-tailed Black Cockatoo was the Wedge-tailed Eagle (*Aquila audax*) which occurred throughout the range of the White-tailed Black Cockatoo. At both Coomallo Creek and Manmanning, eagles were seen regularly throughout the study. At Coomallo Creek there was an active eagle's nest found each year from 1972 to 1976 and at Manmanning in 1971 and from 1973 to 1976.

In both areas the eagles bred in the spring and were usually nesting at the same time as the White-tailed Black Cockatoo, with eggs being laid some time between June and August (Brooker 1976). Each of the eagle nests (used and unused) in both areas were searched regularly between August and January.

During the breeding season, the nest (Figure 57a) was the focus of the eagle's activity and food gathered for the eagle chick elsewhere was brought back to the nest (Figure 57b). Other food was consumed entirely by the adults close to where it was collected so that found in or around the eagle nest represented only about one third or less of the food gathered by them during the breeding season.

Eagles were not seen actually attacking White-tailed Black Cockatoos, but from the reaction of the cockatoos to their presence and the sighting of freshly killed birds on eagle nests (Figure 57c) it was obvious that the eagles do collect free flying cockatoos. Unfortunately, cockatoo bones were picked clean very quickly and were dropped off the edge of the eagle nest where scavengers removed them or they were pushed into the nest lining and disappeared from sight. As a result, the only tangible signs that a White-tailed Black Cockatoo had been eaten were tags found around the nest area, a leg band in an eagle pellet, or some distinctive body feathers scattered about.

In all, eagles accounted for 68 per cent of the known deaths (Table 45). At Manmanning, one female was taken in 1973, 1975 and 1976. Of these three females, two were taken while they were incubating eggs and both were seen out foraging by themselves prior to their being killed (Table 46).

The numbers and classes of birds taken by eagles at Coomallo Creek each year are shown in Table 46 together with the times by

Figure 57a. Wedge-tailed eagle's nest at Coomallo Creek. It was used in 1974 and 1975.

Figure 57b. Floor of eagle's nest showing tag, bones and feathers from a White-tailed Black Cockatoo.

Figure 57c. Freshly killed remains of UM taken from the eagle's nest. One tag from UG also found on nest.

TABLE 46

Predation by Wedge-tailed Eagles

	COOMALLO CREEK					MANMANNING				
	Time Wedge-tailed Eagle chick fledged	Time first White-tailed Black Cockatoo chick fledged	No. of birds known to have been taken by Wedge-tailed Eagles			Time Wedge-tailed Eagle chick fledged	Time first White-tailed Black Cockatoo chick fledged	No. of birds known to have been taken by Wedge-tailed Eagles		
			♀♀	♂♂	Imm.			♀♀	♂♂	Imm.
1972	10 - 20 Dec.	30 Nov.	2		3					
1973	26 Oct - 5 Nov.	9 Nov.	9 (14%)		3	4 Dec.	18 Dec.	1		
1974	9 Oct.	12 Oct.		2		3 Jan.75	21 Nov.			
1975	6 - 16 Oct.	24 Oct.	4			31 Oct.	3 Dec.	1		
1976	20 - 30 Dec.	4 Nov.				15 Dec.	21 Dec.	1		
TOTALS	1972 - 1976		15(8%)	2(3%)	6(2%)			3(9%)		

which the eagle chick and the first White-tailed Black Cockatoo nestling had fledged. The 22 cockatoos taken represented a minimum estimate of predation as they were derived from tags found in or around eagles' nests and do not include those that may have been eaten elsewhere. Birds were certainly killed and eaten in other parts of the study area as I saw an eagle sitting in a low mallee (Eucalyptus sp.) on a rocky outcrop feeding on something. It flew off as I approached and left the remains of FZ, an immature bird that had fledged about one week before. Sometimes only one tag is found in the nest area which indicated that the bird was partially eaten elsewhere and the remains brought in for the eagle chick.

1976 was the only year that White-tailed Black Cockatoo remains were not found around the eagle's nest. That year the nest was on the north end of the study area in a small patch of marri woodland surrounded by cleared farmland, an area not favoured by the birds for breeding. The properties around the area of the nest were owned by people who lived elsewhere and sheep carcasses were left in the paddocks and eagles were often seen feeding on these. From food remains around the nest, the eagles fed more on sheep than in any of the other years (Brooker, pers. comm.). There were only isolated patches of native vegetation around the eagle's nest and the White-tailed Black Cockatoos were never seen foraging there.

In 1974 and 1975, the eagle chick had fledged before the first White-tailed Black Cockatoo nestling and so only the remains of adults were found around the eagle's nest. In 1972 and 1973 the first White-tailed Black Cockatoo nestlings had fledged before the eagle chick and in addition some White-tailed Black Cockatoos often foraged on the edge of the woodland in which the 1972 and 1973 eagle nests were located and both adults and immatures were fed to the eaglets. After the eagle chick had fledged, the eagles continued hunting around the area and used these nests as feeding platforms. As a result, there were White-tailed Black Cockatoo carcasses brought back to these nests well after the eagle chicks had fledged.

In 1973, between August and November, 14 per cent of tagged adult females in the Coomallo Creek area were known to have been taken by eagles. A minimum predation rate of 14 per cent over four months suggested that the eagles may have been selecting tagged adult females as prey in preference to untagged birds.

8.2 Annual mortality.

8.2.1 Adults. Using figures based on the number of tagged birds known to be alive at the end of December in one year and the number of them that were still alive 12 months later, the average survival for both sexes at Coomallo Creek and Manmanning has been calculated and shown on Table 47. The lowest survival was for Coomallo Creek females at 60 per cent and the highest was for Manmanning males at 69 per cent. These figures are based on the assumption that if a tagged bird was not seen in the breeding season following, then it was no longer in the population and was presumed dead.

This assumption was not always valid since some individuals have been seen in the non-breeding season groups but not seen in the breeding area. In two known cases tagged males from Coomallo Creek

TABLE 47

Observed annual survival - adults

Year	No. tagged at end 31 XII	No. left 12 months later	% survival
Coomallo Creek ♀♀			
1971	23	13	57
1972	56	26	46
1973	63	31	49
1974	69	54	78
1975	73	50	68
		Average survival	60%
		Further life expectancy*	2.0 yrs
Coomallo Creek ♂♂			
1971	8	4	50
1972	21	11	52
1973	31	26	84
1974	36	28	78
1975	31	24	77
		Average survival	68%
		Further life expectancy*	2.6 yrs
Manmanning ♀♀			
1971	14	9	64
1972	12	11	92
1973	15	9	60
1974	12	9	75
1975	12	5	42
		Average survival	67%
		Further life expectancy*	2.5 yrs
Manmanning ♂♂			
1971	9	7	78
1972	8	5	63
1973	9	7	78
1974	10	6	60
1975	6	4	67
		Average survival	69%
		Further life expectancy*	2.7 yrs

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* Based on Lack's (1954) formula $\frac{2-m}{m}$ (where m = percentage annual mortality.

who had tagged mates, were seen in the non-breeding season groups with untagged females but had not been seen in the breeding area during the preceding breeding season. Four females are known to have gone to other areas but it is not known if they remated as their mates were untagged. There were not enough data on these occurrences to see which sex remained area specific after remating. The number of birds in this category was small but omission of a few tags could bias the results considerably.

8.2.2 Immature birds. The immature White-tailed Black Cockatoo remains with its parents in its first year until some time shortly before the following breeding season when they become independent (section 9.7.2). This pattern of behaviour allowed crude estimates of immature mortality to be calculated for the period from fledging to the following May (i.e. the first six to eight months) based on tag sightings.

From the end of the 1973 breeding season any searches made of non-breeding season groups also included notes on tagged birds in the groups. Using these sight records, a survival rate was calculated for immatures. This was based on the number of tagged adults seen in non-breeding season groups. These data are given in Table 48 and the average survival for the four years was 49 per cent.

This type of calculation has been carried out for each age group seen in subsequent non-breeding seasons and the survival rates are shown on Table 48. These were minimum figures as some may have been in the groups but not seen and others may have left the area, e.g. the immature bird seen at "Glenvar" twelve months after it had

TABLE 48

Coomallo Creek : Annual survival - immatures

Breeding season (No. of birds)	% still left in non-breeding season groups after: First 6-8 months†	1½ years*	2½ years*	3½ years*
1973 (26)	46%	8%	8%	4%
1974 (38)	53%	18%	16%	
1975 (25)	60%	12%		
1976 (31)	35%			
AVERAGE ANNUAL SURVIVAL:	49%	13%		

† Immatures remain with adults until just prior to breeding season following fledging so these figures would be an accurate estimate of survival.

* These figures are percentage that remain after death and emigration.

fledged. There were too little data to correct the bias introduced as a result of dispersal.

8.3 Discussion. Shooting and collisions with cars are two factors that have only acted on the black cockatoo population comparatively recently. In the case of shooting, only since European settlement, and in the case of collisions with cars, only in the last 50 years. These two mortality factors accounted for 24 per cent of known deaths but because they actively involved people, the return rate from these factors was probably much higher than for traditional factors where the body was seldom seen. Both of these factors will probably become more important in time because as the human population increases and more clearing takes place, the birds will come into conflict with man more often. As native food sources are cleared, the birds will be forced more to exotic foods which are usually grown for some profit to man and any depredations by the birds will result in more shootings.

Based on tag sighting data, the average further life expectancy of adults is two and a half years, yet they only fledge 0.65 young per nesting attempt. Within six to eight months, only 49 per cent of these offspring are left alive. These survivors do not breed for a further three years and it is reasonable to assume that about half or less of the remainder actually survive to breed. These figures are probably too high and for comparison, the Royal Penguin (*Eudyptes chrysolophus*) which is long-lived, has a survival rate of fledglings to breeding age of about 5 per cent (Carrick, 1972).

Assuming that one in five White-tailed Black Cockatoo immatures survives to breed, then it will take a pair of birds at Coomallo

Creek 14 breeding years to produce two offspring who survive and 21 years to produce three. If these figures reflect the true situation then the adults must have an annual survival of between 90 and 95 per cent (from Lack, 1954) if the population is stable. Lack (1954) states that the highest average age may be expected in birds such as the larger petrels or eagles with a clutch of only one egg and several years of immaturity. The White-tailed Black Cockatoo with its low breeding rate and four years immaturity, must have a low adult mortality rate or the population would soon die out.

Because the non-breeding season groups can be searched for tagged birds, it is possible to divide the year into two phases and examine the adult mortality in each. At Coomallo Creek between the end of the breeding season and the following April/May, when the non-breeding season groups start to disperse, the survival of tagged females was 93 per cent and 98 per cent for tagged males averaged over four years. From this time until the birds are breeding, the survival of females is down to 60 per cent and 68 per cent for males. There appears to be some factor operating in the latter phase which results in most of the mortality.

The fact that during the 1973 breeding season eagles accounted for at least 14 per cent of the tagged females in only four months indicates that there may be a bias towards the taking of tagged birds.

Pielowski (1959, 1961) showed that Goshawks (*Accipiter gentilis*) preferred as prey domestic pigeons (*Columba livia*) that differed in colour from the majority of the population. After some experimentation, he concluded that Goshawks seemed to prefer odd, or unusually coloured pigeons. Tinbergen (1960) found that tits (Paridae) tend to select one kind of larval lepidoptera at any given time and believed that the birds were actively searching for these specific larvae and largely ignoring other potential prey. He labelled this phenomenon a 'specific searching image' (SSI). Mueller (1974) set out to delineate the influence of the SSI in prey selection and explore the mechanism by which it is formed in the American Kestrel (Falco sparverius). He found that in his experiments a long-term SSI is the most important determinant of prey selection and that conspicuousness seems unimportant, but several of his experimental birds did show a distinct tendency to select 'odd' prey. Mueller commented that this tendency to select 'odd' prey is probably important because in nature 'odd' animals are less common than in his experimental regime. As a result, a tendency to select 'odd' prey may result in the capture of all of the 'odd' animals in the environment.

Wedge-tailed Eagles will prey on any birds with a body weight in excess of 100 grams (Brooker, pers. comm.) and Galahs, Ravens (Corvus spp), White-tailed Black Cockatoos, Mountain Duck and Straw-necked Ibis (Threskiornis spinicollis) were all taken by eagles at Coomallo Creek. During the period from August to December, the White-tailed Black Cockatoo is common in the area and in the groups of cockatoos are some individuals that are marked in a conspicuous way. When a tagged bird is flying, the sun is reflected off the tags and they are obvious to the naked eye from some distance away. Throughout the period of the study, tagged birds were usually in the minority in groups seen and the sun glinting off the tags may have attracted the eagle's attention and allowed them to keep tagged birds singled out when making an attack. This could lead to differential predation against tagged birds.

In addition to making birds conspicuous, the wearing of tags may affect the birds in other ways. Tags do protrude from the body and as a result they may get caught on some projections (on trees or in hollows, etc.) resulting in wing damage. The tags may also affect the aerodynamics of the wing resulting in altered flight characteristics. There only needs to be a slight disadvantage accruing from the wearing of tags for selection to act against tagged birds and eliminate them from the population. Despite this disadvantage tags are necessary in order to carry out individual behaviour studies and movement studies on wild birds.

9. Behaviour

9.1 Aims of the research into behaviour. The primary aim of this part of the study was to describe and discuss some behavioural activities of an unrestricted colony of White-tailed Black Cockatoo in their natural conditions. The Coomallo Creek population was used in this study because it was a viable population with sufficient nests in an area to ensure that several nests could be observed at once.

The second aim was to carry out a study of an aviary colony in order to clarify certain problems raised by the field studies. The birds' mobility in the field makes data collection difficult during the non-breeding season and the use of aviary studies was to circumvent this problem in addition to augmenting the field observations.

9.2 Behavioural studies on the Psittaciformes. Studies on the behaviour of parrots are few and that of Dilger (1960) was the first detailed account. In a laboratory study on the comparative ethology of the parrot genus *Agapornis*, development of the young, maintenance activities, agonistic and reproductive behaviour are described and discussed. Brockway, studying Budgerygars (*Melopsittacus undulatus*) in aviaries, published a series of papers of various aspects of behaviour; the effects of the position of the nest-entrance and male vocalisations on reproduction (1962); the effects of social influences on reproductive physiology (1964a); a detailed account in which information on the general biology, maintenance, agonistic and other non-reproductive behaviour is given and analysed with respect to function, causation and biological significance (1964b); an account in which the behaviour patterns associated with pairing, precopulatory, copulatory and post copulatory activities are described and their possible function, causation and evolution is discussed (1964c); and an account of the influence of some experimental and genetic factors on the visible courtship behaviour (1974). Willis (1962) studying the Red-backed Parrot (*Psephotus haematonotus*) described behaviour, particularly displacement activities. This study was conducted over a nine month period and was based on aviary studies augmented with some field work. Hardy, studying the Orange-fronted Parakeet (*Aratinga canicularis*) in both laboratory and field, described the epigamic and nesting behaviour (1963) and the flock social behaviour (1965). He later (1966) described a series of experiments designed to reveal the importance of specific, racial and individual characteristics of sociality and postulated their part in the evolutionary process. Zann (1965) in a laboratory study on the Quarrion (*Nymphicus hollandicus*) gave an account of its general biology and descriptions of maintenance, agonistic, reproductive and flocking behaviour. Power, studying the Orange-chinned Parakeet (*Brotogeris jugularis*) in captivity, described the aggressive and appeasement behaviour, the peck order, territoriality, reactions to a predator, displacement behaviour and vocalisations (1966). He subsequently (1967) described the epigamic and reproductive behaviour and particularly the behaviour of individuals and members of pairs. Buckley (1968) studying the Blue-crowned Hanging Parrot (*Loriculus galgulus*) and the Vernal Hanging Parrot (*L. vernalis*) in aviaries, described their maintenance, agonistic and reproductive behaviour.

Pidgeon (1970) made the first detailed study on any of the cockatoos and described the individual and social behaviour of the Galah (*Kakatöe roseicapilla*) based on both aviary and field studies.

There are several more accounts of more restricted aspects of behaviour dealing with the Order generally or on a more specific level. Brereton and Immelmann (1962) investigated head scratching in the Psittaciformes and Smith (1970) commented on the use of the foot in feeding with special reference to parrots. Harrison (1973) described the nest-building behaviour of Quaker Parrots (*Myopsitta monachus*) in captivity and Potts (1976, 1977) described the comfort movements and the agonistic behaviour of the Kea (*Nestor notabilis*).

Behavioural research on parrots has been confined, almost exclusively, to studies conducted in aviaries. As a result, there has been an emphasis on behaviour associated with comfort, maintenance and agonism; activities which are commonly seen in aviaries. There are fewer studies on reproductive behaviour and of those that been conducted only Willis (1962) and Pidgeon (1970) used adult birds taken from wild populations. The remainder used birds obtained commercially and in some cases these were from domesticated strains. As a consequence, there is a conspicuous lack of detailed knowledge of the behaviour of natural parrot populations and the part behaviour plays in the regulation of these populations. The imposition of space limitations on animals by confinement of any description, may result in modifications of the behaviour and produce "artifacts of behaviour". Without detailed knowledge of the behaviour of animals in free-living populations, predictions about wild populations, made on observations from caged animals, are potentially misleading.

The White-tailed Black Cockatoo was the only cockatoo which had not been bred successfully in captivity by the start of this study (Lendon, in Cayley, 1973). For this reason studies of reproductive behaviour had to be undertaken in the field.

9.3 Methods

9.3.1 The field colony.

In order to observe behaviour associated with breeding, a hide was set up on a three-metre tower in the centre of a group of trees (Figure 10). This group of trees was isolated by paddocks and uncleared heathland from other such groups. (Figure 58 shows the location of the hide in relation to nest hollows.) There were 15 hollows large enough for the birds to use that could be observed from the hide.

In 1972, weekly watches were kept on four nests. These weekly watches were carried out from 1600 hours until dark and then from dawn to 1200 hours the following day. These were conducted from the time the first eggs were laid until all the nestlings had left the hollows. In 1973 and 1974, continuous watches were conducted each week from 1300 hours until dark and from dawn to 1300 hours the following day. These were conducted from before egg-laying until the nestlings fledged in 1973 and until all the nestlings had hatched in 1974.

9.3.2 The aviary colony.

Three experimental aviaries were used in the course of the study.

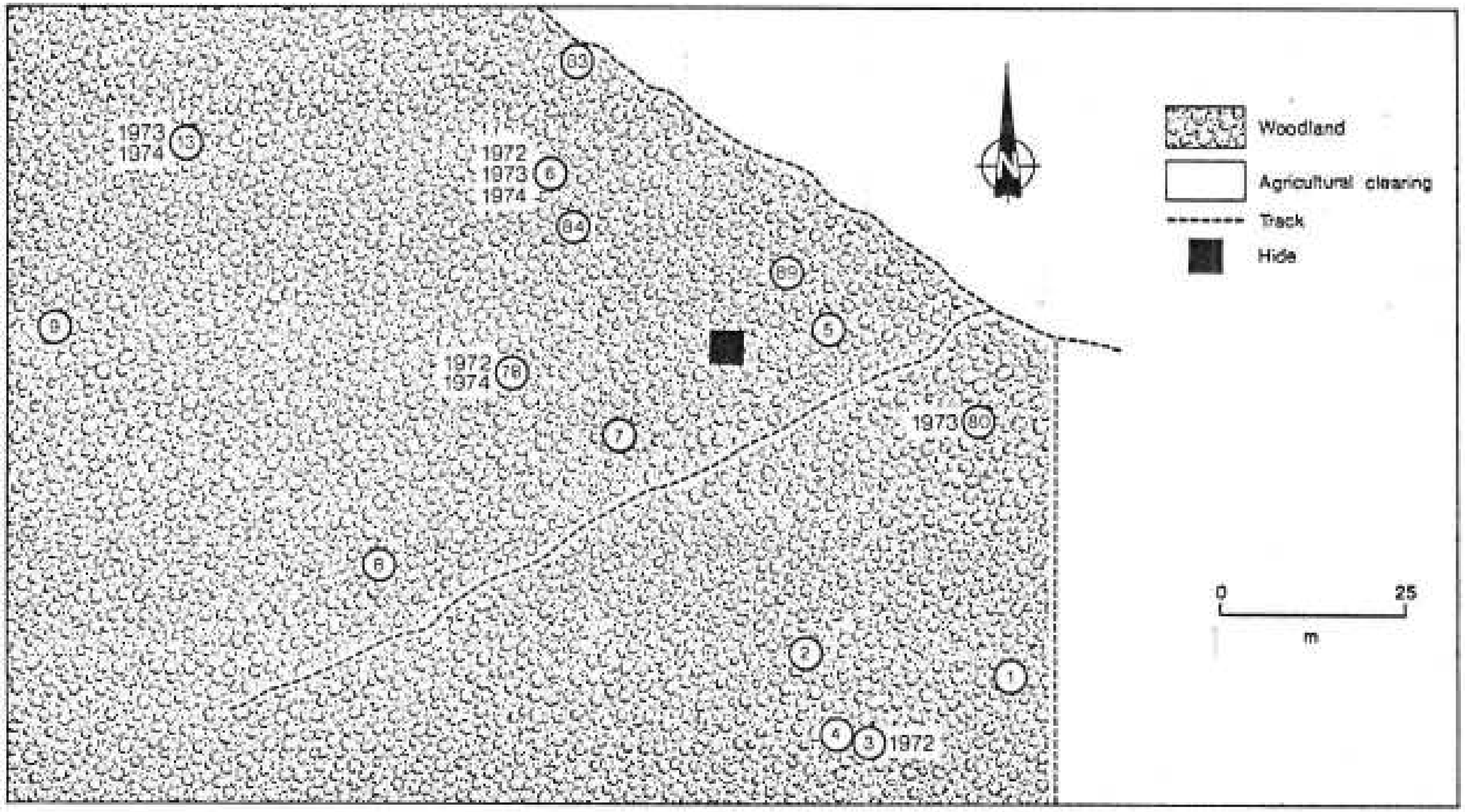

Figure 58. Location of hide in relation to available nest sites. Coomallo Creek 1972-1974.

The first (Big Aviary) was 12.2 metres long and 6.4 metres wide and high made out of aluminium angle supports and wire mesh. It was constructed around a large wandoo which had been trimmed to allow the cage to be built around it. By the time observations were begun the birds in the aviary had ringbarked the tree and killed it. There were two hollows attached to the dead tree and a further two more attached to the sides of the aviary.

Observations were made from a hide 12 metres from the cage.

The second aviary (T-aviary) was built in the form of a large T and was built out of frame sections 2.4 metres square covered with wire mesh. The aviary was 2.4 metres high and 22 metres long across the top of the T and 12.2 metres along the upright of the T. Eight hollows were supplied in the aviary, two in each arm and in the centre section. Perches were supplied in each arm and in the centre section. Observations were made from a hide located in the middle of the top of the T.

The third aviary (Small Aviary) was built out of 2.4 metre sections covered with wire and was 4.2 metres long and 2.4 metres wide and high. A perch was supplied at each end of the aviary. Observations were made from a hide built at one end. This was the only aviary with a concrete floor.

The birds were fed sunflower seed, and this was supplemented with various other items such as pine cones, marri nuts and

Banksia grandis flowers and cones as often as they could be obtained. Water was supplied in stock troughs on the floor.

The use of these aviaries in the various experiments conducted will be detailed in the presentation of the experiments.

9.4 Description of behaviour

9.4.1 *Introduction*. The study of the behaviour of the White-tailed Black Cockatoo began with a qualitative description of the behaviour exhibited by birds in both the field and aviary. There were two basic types of behavioural units: activity patterns (i.e. movements and postures) and vocalizations, although some vocalizations formed part of some activity patterns. In the following sections the behavioural units described may consist of several component movements (for example, autopreening consists of several different movements) but the units have not been broken down to their components because it seemed that the unit was a more useful basis for the subsequent analysis of its function.

In the following section the behavioural units have been presented in various groupings. Each group has an apparent functional correlate (e.g. maintenance and comfort behaviour, locomotion, etc.). There is a danger in such categorization as some units may have several functional correlates and this would result in hybrid classification. Bearing this in mind, impressions gained during the descriptive phase of the study formed the basis for the following classification. The significance of this classification was then tested in quantitative analyses of the behavioural units.

9.4.2 Activity patterns.

9.4.2 (i) Maintenance and comfort behaviour. These consist of activities carried out to maintain the individual's continued existence and well-being.

9.4.2 (i)(a) Feeding. White-tailed Black Cockatoos are gregarious and feed in trees, low bushes, or on the ground. They usually feed in groups which move steadily over the food source, each individual feeding in one spot, moving on and then resuming feeding. Occasionally, individuals will take off and fly over those in front, land and start feeding. On the ground, this type of feeding action causes the group to move steadily across the food source. Much the same type of action is used when feeding in bushes and trees. This type of group feeding movement has been termed "drifting" by Hinde (1952) and occurs in Galahs (Pidgeon 1970) and Red-tailed Black Cockatoos (pers. obs.).

Seed is picked up between the mandible tips and husked using the tongue and mandible tips. The tongue is used to clamp the seed against the inside of the upper mandible while the edge of the lower is applied to the seed to crack the husk (see Homberger and Ziswiler [1972] for an accurate description of this process). The seed is rotated using the tongue and when the seed is clean, the husk is discarded and the seed swallowed whole. Even seeds of the Marri which are among the largest eucalypt seeds (up to 12 mm long) or very large pine seeds (15 mm long x 6 mm wide) are swallowed whole.

Seed may be removed directly, leaving the damaged seed pod on the plant as seen on some <u>Hakeas</u>, or the bird may bite off a single pod or cluster of pods at the stalk. The pods are held in the foot while the seeds are removed (Figure 59). This technique is invariably used when feeding on Marri as the fruits hang down and have to be removed before extracting the seed. The fruits are bitten off and lifted in the bill, then transferred to the foot. This transferring results in the dropping of one fruit out of ten before it has been eaten (Saunders 1974b). As a result, there is food littered on the ground during a feeding bout and this is exploited even while there is food still on the plant. The Forests Department took advantage of this "clumsiness" by collecting dropped pine cones (both uneaten and partly eaten), ripening them and extracting seed, thus eliminating the need to climb the trees to get seed cone (Perry 1948). Some birds often walk around on the ground picking over dropped fruits while others are feeding above. Even in cages where food is provided in bowls, the birds seem to prefer to scatter it around on the floor and walk around picking it over.

A number of species of plant shed their seed after fire and the birds will readily come to the ground even while the bush is still smoking, and feed on this seed.

The birds will sometimes carry food with them when they fly off. This is usually carried in the bill.

9.4.2 (i)(b). <u>Drinking</u>. White-tailed Black Cockatoos are seed eaters and usually drink every day, usually mid-

Figure 59. Food being transferred from the bill to the foot.

morning and late afternoon. They will drink from any accessible water source and they usually fly to some vantage point (tree, mill, tank or fence) before moving in to drink. From the vantage point the birds fly to the ground or to a point several metres from where they are going to drink and then walk in. They appear to be very wary when drinking and by landing some distance away they are able to survey the watering point thoroughly. This has proved advantageous as the feral cat (*Felis catus*) in some areas lies under stock troughs and preys on birds coming in to drink. White-tailed Black Cockatoos, and Red-tailed Black Cockatoos which survey the area before drinking are rarely caught this way whereas Galahs and Corellas which land directly on the trough are often caught (pers. obs.).

The birds lean forward and dip the mandibles into the water with the bill half open. The lower mandible is filled with water, the tongue being pushed up and down to help the water in. The bird then raises its body and tilts its head so that the water runs down into the crop when the bird swallows. This action is repeated until the bird has taken sufficient.

The observed number of dips in a drinking bout varies from two to 21 seen on a very hot afternoon by a female which still had a nestling. After drinking, the bird invariably flies directly to a nearby tree or perch, waiting until the group has finished drinking before flying off.

9.4.2 (i)(c). *Normal perch position.* In this position, the feathers are ruffled, the lower mandible is hidden by feathers* and one foot may be drawn up into the feathers of the abdomen (Figure 60). The eyes may be closed.

9.4.2 (i)(d). Defecating. The body is lowered downwards and the feathers of the lower back and crissum are ruffled. The same action is followed when the bird is on the ground with the body lowered so that the cloaca almost touches the ground. After voiding the bird shakes its tail briefly, resumes the normal perch position although it may shake soon after.

9.4.2 (i)(e). Chewing. White-tailed Black Cockatoos, in common with many of the parrots (*Agapornis*, Dilger 1960; Red-backed Parrot, Willis 1962; Budgerigar, Brockway 1964b; Orange-fronted Parakeet, Hardy 1963; Quarrion, Zann 1965; Galah, Pidgeon 1970; Red-tailed Black Cockatoo, pers. obs.) spend a considerable amount of time in the wild and in captivity engaged in chewing activities. A wide range of objects is bitten and chewed. In the case of a perch, the bird may bend down and bite off large slivers of wood (Figure 61) which are picked up in the bill, transferred to one foot and held there as the bird chews them. Dilger (1960) concludes that this behaviour maintains the maxilla at a normal length in *Agapornis*, and states that when access to material to chew is denied the tip of the maxilla tends to become abnormally long. Chewing in the White-tailed Black Cockatoo may well have the same function.

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* The generic name *Calyptorhynchus* means "hidden bill".

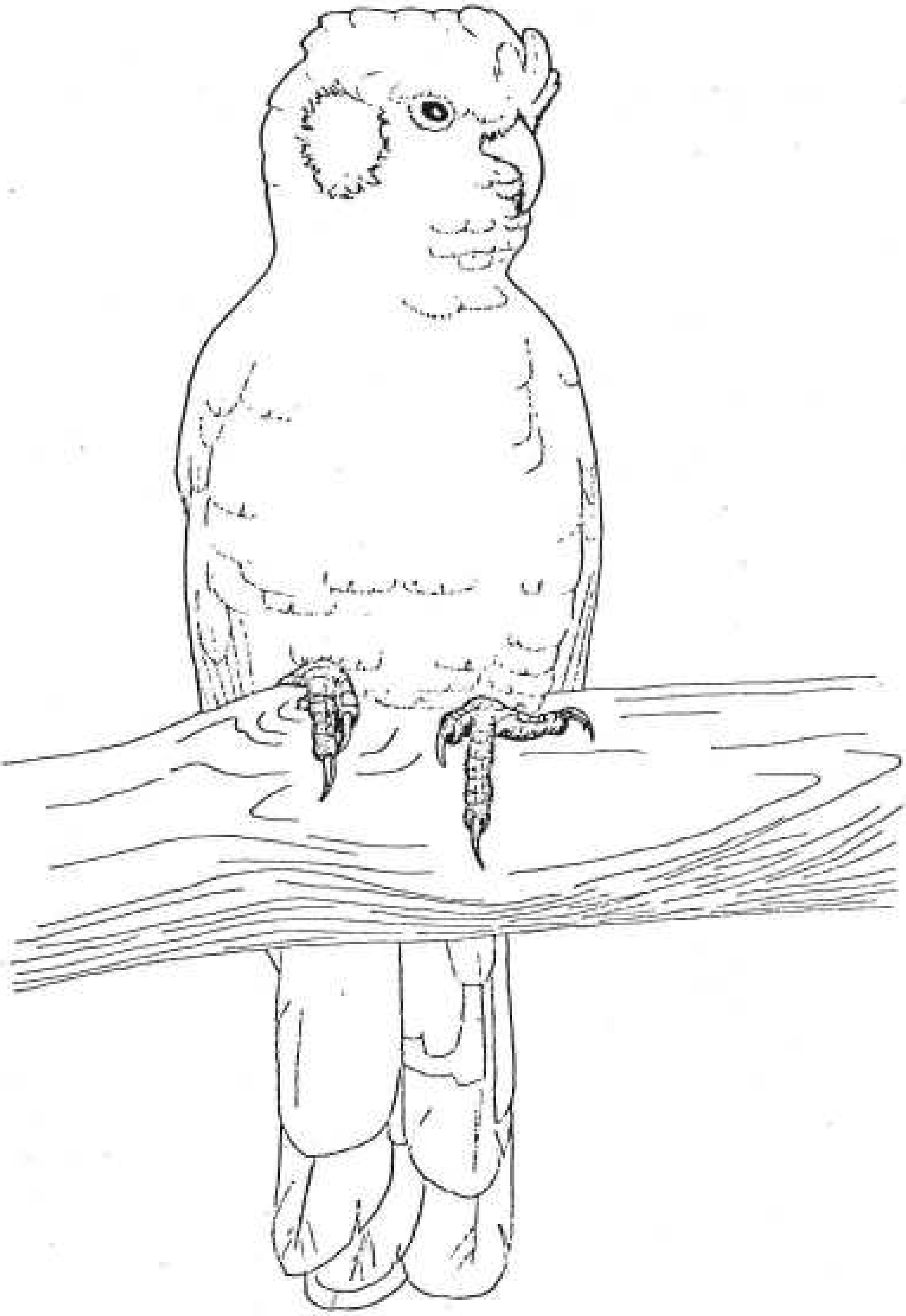


Figure 60. Normal perch position.

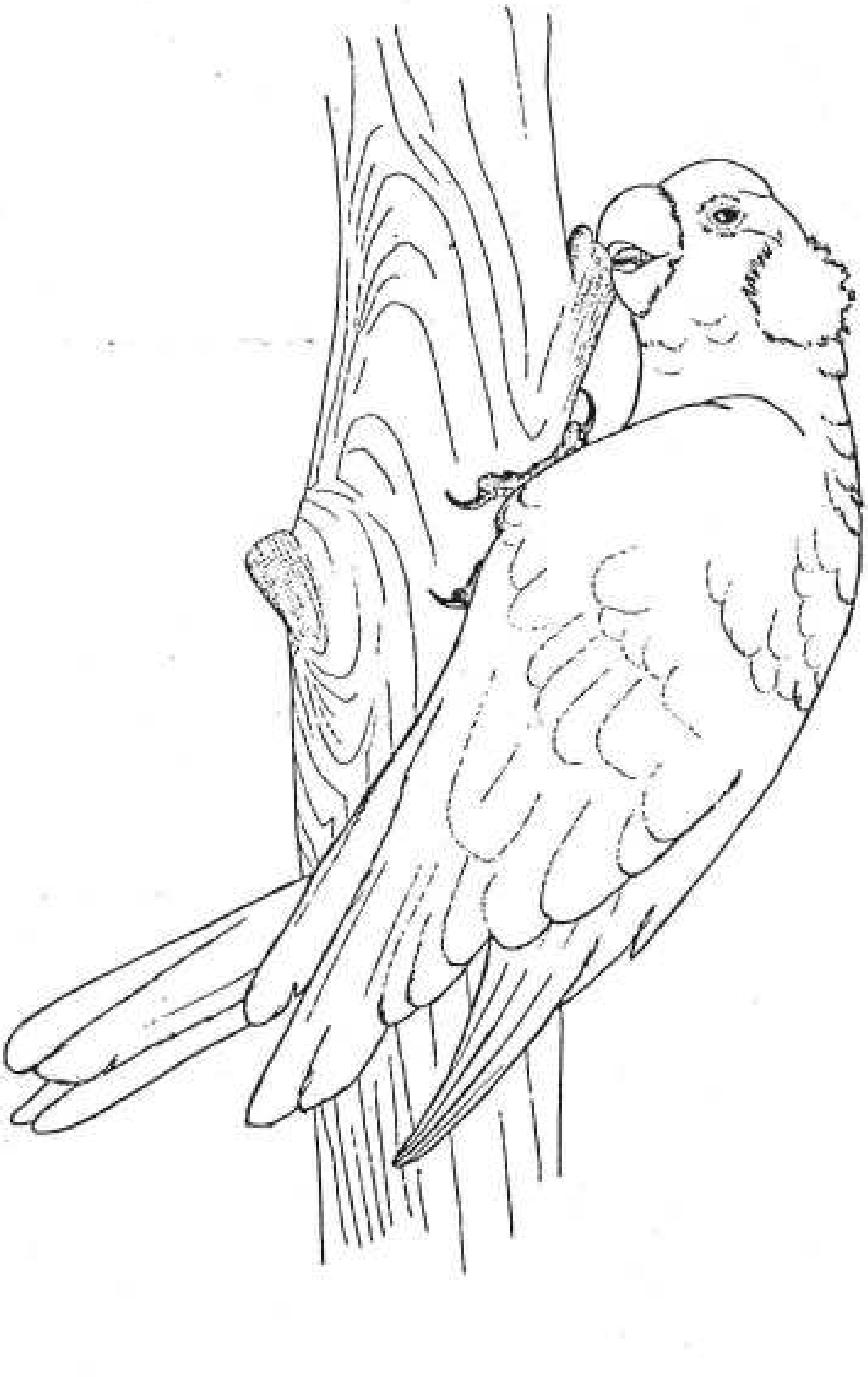


Figure 61. Chewing at perch.

9.4.2 (i)(f) Bill stropping. The bill is wiped across some object, first one side then the other in the manner in which a knife is sharpened on a steel. The bird may be walking or stationary when performing this action and it may be done once or several times. It is commonly carried out after feeding, drinking or chewing when foreign particles may be adhering to the bill. This has been termed bill-wiping by Zann (1965) and Pidgeon (1970).

9.4.2 (i)(g) Bill grinding. The edge of the mandible is moved up and down on the corrugated surface on the inside of the maxilla. Sometimes a grinding motion is used and the noise produced may be audible several metres away.

Homberger and Ziswiler (1972) in an investigation on the functional morphology of the bill of parrots provide a detailed description of this bill-honing process and note that in the 17 species of parrot and cockatoo that they observed the birds only perform this behaviour when they are in a peaceful, settled mood and any disturbance stops it. This appears to be the case with both White-tailed and Red-tailed Black Cockatoos which only perform bill grinding when they are in the normal perch position. Any disturbance results in the bird adopting an alert posture and bill grinding ceases.

Homberger and Ziswiler found that the functional significance of bill grinding consists in modelling of the final narrower section of the maxilla and in sharpening the cutting edge of the mandible. In addition, the corrugated lining on the inside of the maxilla is modelled out and this section plays a vital part in the process of husking the seed. It is this section that provides the anvil on which the seed is held by the tongue while the mandible cuts into the seed.

This interpretation of the function of bill grinding is confirmed by the structure of the maxilla and mandible of one adult female collected in a pine plantation. One side of the cutting edge of the mandible had broken off for some reason so that the grinding action on the inside of the maxilla resulted in only a portion of one side being ground. The unground side continued growing, as did the unbroken tip of the mandible resulting in a deformed bill resembling a large pair of shears. The maxilla was 34% longer than the normal length. This bird was in very good condition with a crop full of husked seeds when collected.

Nestlings are able to bill grind by 5 weeks old and do it after being fed.

9.4.2 (i)(h) Scratching. The head and bill are the only areas scratched and this is carried out by raising the foot under the wing and at the same time lowering the head towards the foot. This is the "direct" method described by Simmons (1961) and called "under" by Brereton and Immelman (1962). The claw of the long centre toe is used in a series of rapid vertical movements of the foot. The head is moved in relation to the foot to enable different areas to be tended.

Any persistent foreign particles remaining on the bill after bill stropping are removed by scratching.

9.4.2 (i)(i) Foot care. The feet are cleaned by the bill, the foot being raised under the wing and the head is lowered to it. Debris is cleaned off the legs by nibbling with the bill and the toes and claws are cleaned in the same manner. They are also cleaned by drawing them through the partly opened mandibles.

9.4.2 (i)(j) Resting and sleeping. Resting and sleeping involve two positions. The bird sits with its head forward and the bill partially hidden in the feathers of the breast or the head may be turned over one shoulder and the bill buried in the scapulars. In both positions the body feathers are partially ruffled and one foot is usually drawn up into the feathers of the abdomen. The eyes may be open or closed.

Both positions are used at night and during the day and both are used during brief rest periods between other activities when perched. This differs from the Galahs which used the head-forward position for brief rest periods (Pidgeon 1970).

Young nestlings often sleep or rest lying down on their abdomens with their head out and turned to one side. The wings are held out from the body and drooped down. In this position they can see straight up the hollow to the entrance which they can not do easily when standing up. As they get older they start to sleep standing up, first with both feet on floor, then as they are able to balance more efficiently they draw one foot up. By the time they leave the hollow they only sleep standing up.

9.4.2 (i)(k) Stretching. When stretching, one wing and the leg on the same side of the body are extended down and backwards. The tail is fanned in the direction of the extended wing (Figure 62). This position is held briefly then the normal perch position is resumed. This process may be repeated on the other side of the body. After settling the feathers, which may involve slight raising and ruffling of the flight feathers, both carpal joints are usually raised up towards each other over the back, the head is lowered and the body bent forward in the form of a wing arch (Figure 63). The tail is occasionally wagged briefly. The normal perch position is then resumed.

These activities are similar to those described for a number of parrot species: Dilger (1960) noted that *Agapornis* stretch but made no mention of wing arching; Willis (1962) observed wing-arching and wing-leg-flex in the Red-backed Parrot; Brockway (1964b) noted stretching in the Budgerigar and said that wing arching usually followed; Zann (1965) observed wing-leg-stretch followed by wing arch in the Quarrion; Buckley (1968) stated that wing stretch is usually followed by wing arching in the Hanging Parrots; Pidgeon (1970) noted both wing-leg-stretch and wing arch in the Galah but fails to mention if they occur in juxta position; Potts (1976) noted a correlation between wing-leg-stretch and both wings stretch (wing arch) stating that the correlations "may be

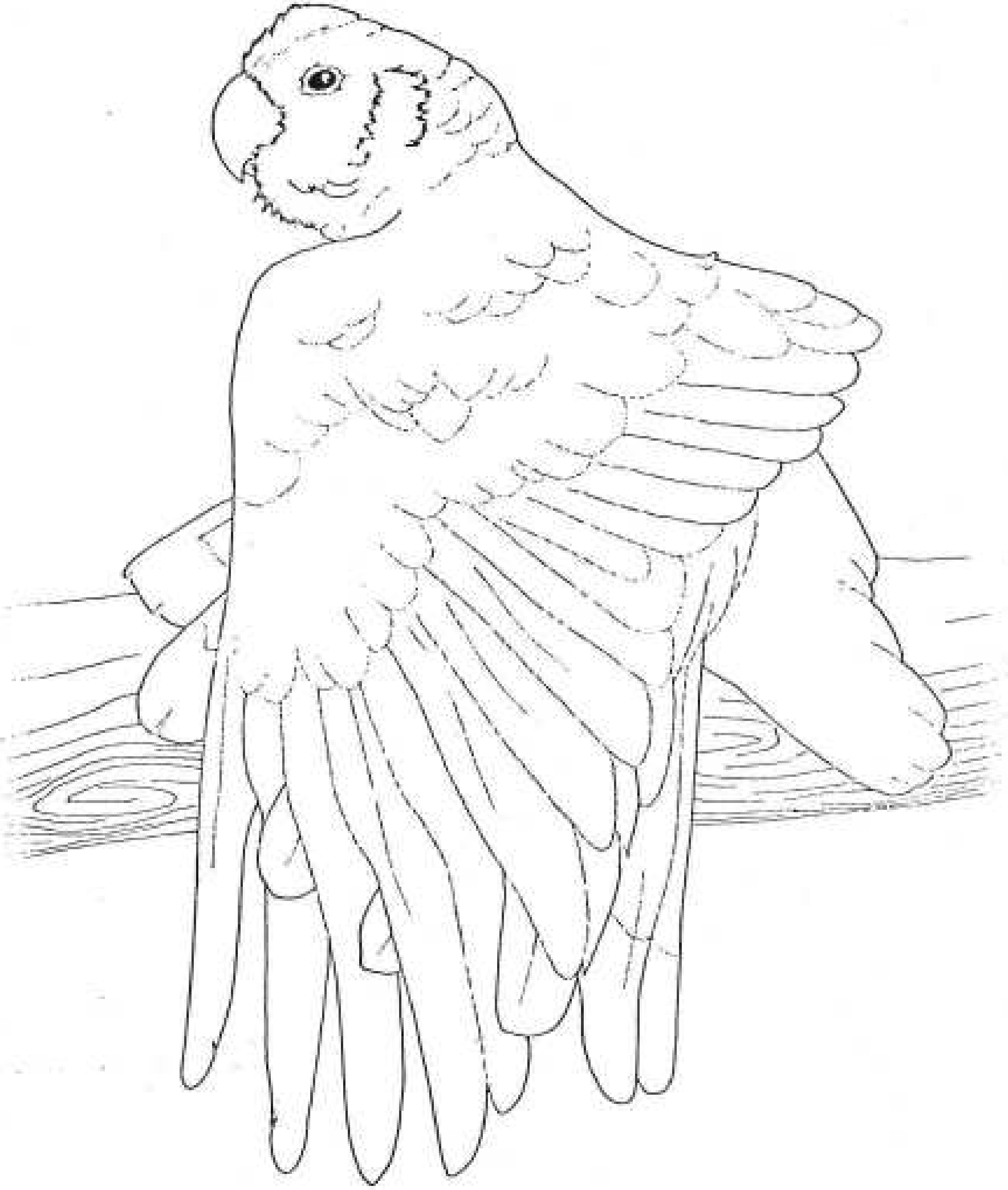


Figure 62. Stretching.

Figure 63. Wing arch.

consequences of simultaneous propriostimulation from inactive muscles"; and the Red-tailed Black Cockatoo performs wing stretch usually followed by wing arch (pers. obs.).

9.4.2 (i)(l) Jaw stretch. The bill is opened widely and the head raised slightly in what resembles a yawn. In fact all of the above workers except Buckley (1968) and Potts (1976) have called this activity "yawning", the other two calling it jaw-stretch. The action appears to be a jaw-stretching action and is often carried out after long periods of inactivity.

9.4.2 (i)(m) Shaking. The feathers are ruffled and the body and head are shaken by a series of rolling movements from side to side. On some occasions only the head is shaken and this occurs quite often after drinking when there is water dripping off the bill. On some occasions the tail may be wagged from side to side during shaking and when this occurs it is not fanned.

This activity has been described for Agapornis (Dilger 1960), Budgerigars (Brockway 1964b), Quarrion (Zann 1965), Hanging Parrots (Buckley 1968), Galahs (Pidgeon 1970 mentions it briefly in the section on preening), and the Kea (Potts 1976). Most of these workers refer to shaking as serving to settle the feathers or dislodge some foreign matter on the bird.

9.4.2 (i)(n) Sneezing. Occasionally a bird will explosively expel air out of its nostrils while bobbing its head. This has an appearance of a sneeze and sometimes occurs in young birds after drinking. From the way small droplets of water are expelled from the nostrils it seems that the bird may have got some water into the trachea and the sneeze is a response to clear it .

The Kéa is the only parrot species for which there is any reference to sneezing (Potts 1976).

9.4.2 (i)(o) Autopreening. Cullen (1963) proposed the term "autopreening" for those occasions when a bird preens its own plumage and this term is used here.

White-tailed Black Cockatoos spend a lot of time maintaining the body surfaces. This is necessary to care for the feathers and to remove ectoparasites such as feather lice (*Mallophaga*).

There are two types of preening movements involved. The first consists of nibbling the feathers or skin with the bill and is used for the small feathers of the body and for ectoparasite removal. The other method is the drawing of feathers through the bill and this is used for the remiges and rectrices (Figure 64).

A preen gland is present on the back near the base of the tail and when preening, this gland is nibbled and the bill is wiped over it. Oil is probably placed on other parts of the body during preening following use of the preen gland. It is not used in all preening bouts but in a prolonged bout it is used at least once.

The activities associated with autopreening are essentially similar to those described for *Agapornis* (Dilger 1960), Red-backed Parrots (Willis 1962), Budgerigar (Brockway 1964b), Quarrion (Zann

Figure 64. Preening rectrices.

1965), Hanging Parrots (Buckley 1968), Galah (Pidgeon 1970), and Kea (Potts 1976), except Potts made no mention of a preen gland.

No predictable pattern appears to be followed during preening but preening of the neck and breast regions occur most commonly. Virtually all of the body except for the head and upper neck are accessible to autopreening.

9.4.2 (i)(p) Temperature regulation. White-tailed Black Cockatoos sleek their feathers when they are warm and fluff them out when cold. In air temperatures up to about 30-33°C they can maintain a normal plumage posture. Once the temperature rises above this, then the feathers are sleeked, the carpals are held out from the body and drooped, the bill is half opened and the birds pant. This posture may be maintained for long periods over the heat of the middle of the day until the ambient temperature falls.

9.4.2 (i)(q) Alert posture. The alert posture adopted by the bird depends on the strength of the stimulus it receives. An unusual sound may result in the bird pausing in its activity, raising its head and looking round, then resuming its activity.

A loud sound or unusual movement, such as a person approaching, results in the bird standing erect with the legs extended, feathers sleeked and the neck extended. The feathers of the small crest may be raised and the feathers around the lower mandible are sleeked exposing the bill. In addition a short alert call may be given (see Vocalizations section). The assumption of this posture often results in other birds around it also adopting the same posture.

This posture is held until the bird is certain that no threat is posed to it, in which case it resumes its other activities.

9.4.2 (ii) Locomotion.

9.4.2 (ii)(a) Walking. White-tailed Black Cockatoos walk with a slow waddle imposed on them by their short tarsi. Both flat and inclined surfaces are covered on foot and the birds usually walk or climb short distances rather than fly.

When climbing the bill is used as a third leg. The body and neck are stretched up, the bill is hooked around a purchase point and the feet walked up to a point just below the bill. The bill is released and moved up. When descending, the bill is hooked around a purchase point level or lower than the feet and the body swung down to enable the feet to make contact lower down. Their dexterity is such that they are able to climb up the side of a wire cage using the bill as a third leg while holding another object (such as a marri nut) between the mandibles.

This "three-legged" movement has been called "tripodding" by Rowley (pers. comm.) in the Galah and has been described for: *Agapornis* (Dilger 1960); Red-backed Parrot (Willis 1962); Budgerigar (Brockway 1964b); Quarrion (Zann 1965); Hanging Parrots (Buckley 1968) and Galah (Pidgeon 1970).

9.4.2 (ii)(b) Sidling. When travelling short distances, the birds often move sideways with the head turned in the direction of travel. This is usually done on narrow perches and if longer distances are involved, the bird turns its body in the direction of travel and walks.

9.4.2 (ii)(c) Flying. Flying involves slow regular wing beats of deep amplitude and a ground speed of about 30 km/hour. The wing beats on taking off are slightly faster than those of normal flight.

On leaving the nest hollow for the first and only time fledgling birds are able to fly quite strongly and after the first few hundred metres it is difficult to distinguish between their flight and that of their more experienced parents. To be able to do this they must have exercised their wings inside the hollow prior to fledging. They do this by stretching and arching their wings inside the hollow. The nestling which I successfully hand-reared from about 30 days old frequently performed these actions. On one occasion when it was about 70 days old in one 20-minute period it stretched its wings 8 times to each side followed in each case by a wing arch. The frequency of this action is far in excess of that seen by birds which have fledged. In addition, by about 35 days old it had started flapping its wings frequently. In the confined space of a hollow there is insufficient room for a nestling to extend its wings fully in a flying attitude so the birds extend their wings up the spout of the hollow and flap them in what space they have. Occasionally this results in a broken wing because the bird has flapped the wing too hard against the wall of the hollow.

Although large nestlings climb up the hollow and sit in the entrance they were never seen flapping their wings in this position. Possibly the risk of overbalancing and falling out is too great.

Unlike Galahs (Pidgeon 1970), White-tailed Black Cockatoos seldom glide when flying. Gliding is usually done just prior to landing, when weaving through trees or when flying during very windy weather.

Watters (1968) in his thesis on the taxonomy of the Psittaciformes calculated the aspect ratio $(\frac{\text{wing span}}{\text{wing area}})$ and wing loading (gm/cm^2 of wing area) for a range of species including the White-tailed Black Cockatoo. The aspect ratio for this species was determined at 0.556 and the wing loading at 0.377. Both these values are slightly lower than those for the Galah (0.610 and 0.406). Pidgeon (1970) in his discussion on the aerodynamic capabilities in relation to feeding and movement patterns noted that "there is a trend of decreasing aspect ratio and wing loading from the nomadic tree feeding species to the sedentary ground feeding species" and gave an explanation of why he felt this was so. He noted that the Galah has a higher aspect ratio than sedentary species of parrot but lower than other nomadic species. He stated that this probably allows the Galah to move fairly long distances and to maneouvre among trees and that the higher wing loading in relation to other ground feeding species may be the cost of a large body size and high aspect ratio.

This may be true of the White-tailed Black Cockatoo which is both a ground and arboreal feeder as well as nomadic, moving long distances quite quickly.

9.4.2 (ii)(d) Landing. When landing on a perch or on the ground the birds generally glide and stall onto the perch surface by lowering the body, fanning the tail and, just prior to contact, extending the legs down and lifting the wings up. After landing the wings are settled and the tail closed. If the landing is a heavy one and the bird overbalances, the wings are flapped to regain the erect position prior to settling.

Although fledglings are able to fly strongly as soon as they leave the nest, their landings are often very poor. Their inexperience leads them to select places to land which are often unsuitable. For example, small branches which will not support their weight, or leaves in the canopy through which they crash before finding something more substantial to settle on. Until they gain some experience in landing correctly, each landing may involve several aborted attempts before a successful one is negotiated. During this learning period they are vulnerable as they occasionally end up on the ground after a particularly unsuccessful landing.

9.4.2 (ii)(e) Pre-flight crouch. Flight intention movements consist of sleeking the plumage, crouching the body, flexing the legs and stretching the head out and down. The wings may be closed or half raised and the tail may be fanned.

When taking off the bird raises its wings to their full extent and springs into the air, beating the wings strongly down to carry the bird into the air. Flight does not always follow the adoption of the pre-flight crouch but flight is always preceded by it.

This posture is similar to flight intention described for Agapornis (Dilger 1960), Hanging Parrots (Buckley 1968) and Galahs (Pidgeon 1970).

9.4.2 (ii)(f) Walking with head twist. Some caged individuals often take several steps along a perch then turn round by twisting the head over the shoulder and then turning round in the direction the head is turned. They then walk several paces and twist round. This may be performed once or twice or may go on for long periods.

On other occasions they may twist round and round on the spot without walking or they may twist the head over the shoulder then swing it back and twist it round the other shoulder then back and so on. None of these actions has ever been seen to be performed by any bird in the field.

These particular activities have not been described in any of the parrots whose behaviour has been described in the literature.

9.4.2 (iii) Agonistic behaviour. Those activities concerned with aggression.

9.4.2 (iii)(a) Bill face. The bill of the White-tailed Black Cockatoo is very powerful and is capable of inflicting considerable damage to other birds. The capabilities of the bill were convincingly demonstrated by an aviary female which crushed the skull of a rat (Rattus spp.) which approached the feed bowl while the female was feeding. Despite this power, there were no instances seen in aviary or field where one bird caused physical damage to another in an agonistic encounter.

Turning the head with the feathers sleeked so that the bill (closed or partially open) is fully exposed and is facing towards another bird is the lowest manifest form of aggression. It may occasionally be accompanied by a harsh Squawk (Vocalizations section). This facing of the bill towards another has also been regarded as an aggressive act in the Galah (Pidgeon 1970).

9.4.2 (iii)(b) Bill face with gape.

In this posture the bird stands erect with its plumage sleeked down, head extended towards another bird with the bill opened wide. This is usually accompanied by a loud Squawk (Figure 65). On some occasions the bird may attempt to nip the other bird, usually around the bill or around the toes. On all occasions observed the other bird had moved in time to avoid the nip.

Very rarely does aggression take the form of a "fight" with both individuals attempting to bite. On the several occasions observed where two individuals gave bill face with gape to each other and attempted to bite, one moved away very quickly before any damage was done. On occasions one leg may be raised and pushed against the breast of another if the first bill face with gape does not cause the bird to move away.

All parrots whose behaviour has been described used the bill

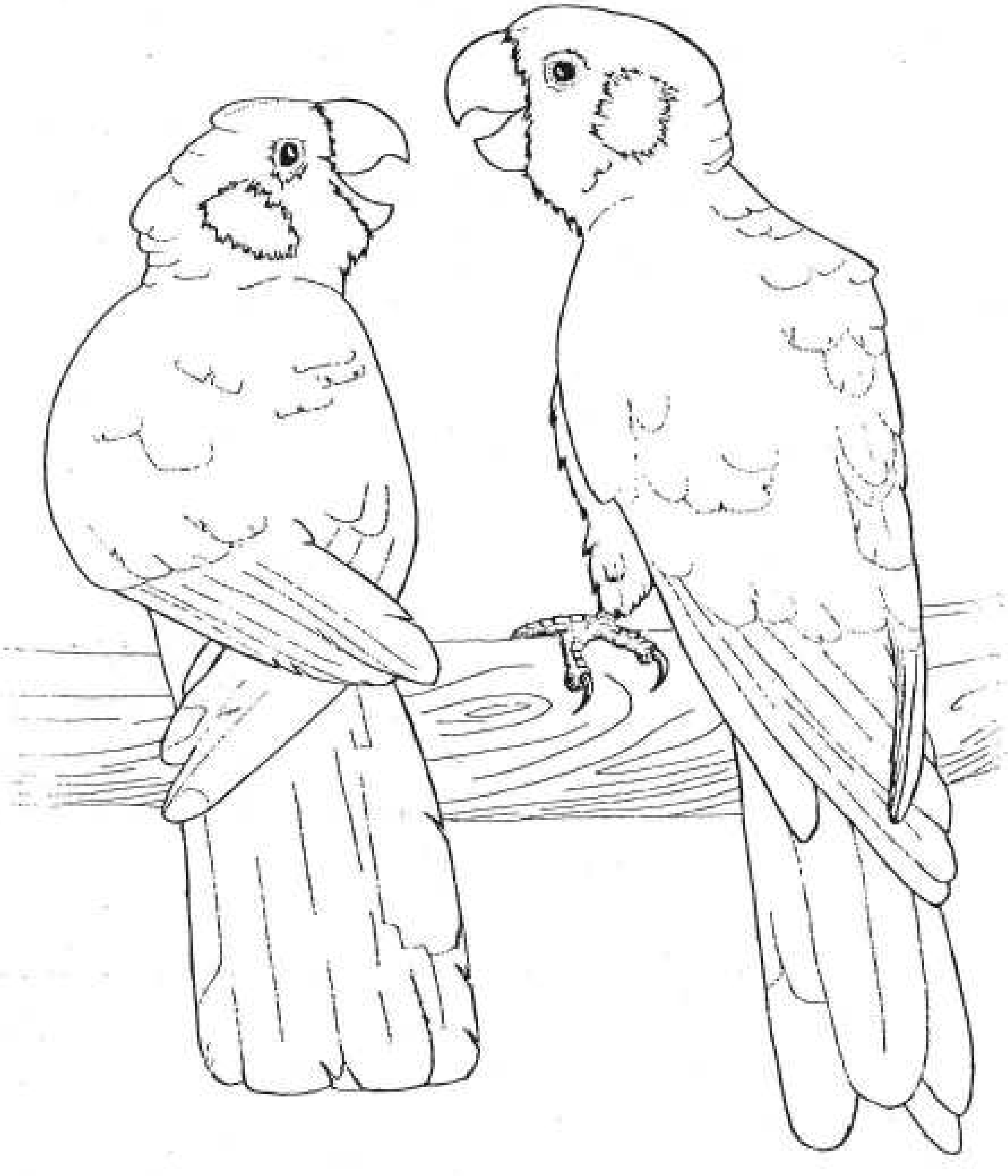


Figure 65. Bill face with gape.

in aggressive encounters: Agapornis (Dilger 1960); Red-backed Parrot (Willis 1962); Budgerigar (Brockway 1964b); Orange-fronted Parakeet (Hardy 1963); Quarrion (Zann 1965); Orange-chinned Parakeet (Power 1966); Hanging Parrots (Buckley 1968); Galah (Pidgeon 1970); and Kea (Potts 1977).

9.4.2 (iii)(c) Move towards. A bird may approach another in several ways but if it moves towards the other, facing towards it with its plumage sleeked and bill fully exposed it constitutes an aggressive act. This is a form of bill face but with a movement towards the other bird.

9.4.2 (iii)(d) Bill face and pre-flight crouch. The bird adopts the pre-flight crouch and leans forward facing another bird while Squawking loudly. If the other bird is near, it may lunge and attempt to bite. If the other bird is some distance away, for example, near the bird's nest hollow, it may fly directly to the intruding bird. There is a very strong tendency to fly at or after another bird in this posture and this may result in a chase.

9.4.2 (iii)(e) Squeak/Chatter with head bob. All of the displays involving the Squeak/Chatter (Vocalizations section) have only been seen from males directed towards other males.

A harsh Squeak/Chatter is uttered, the head may be bobbed once or repeatedly and the tail fanned (fully or partially) with each head bob.

9.4.2 (iii)(f) Squeak/Chatter with pre-flight crouch. The male adopts the pre-flight crouch and draws itself erect while uttering the Squeak/Chatter. The tail may be fanned at the same time. Once the body is erect the whole action may be repeated or the male resumes the normal perch position. The male may resume the normal perch position without drawing itself erect and in other variants it may wave its head from side to side in the crouch.

This action may be given to another male nearby or to one some distance away and there is a strong tendency to fly at or after the other male. This may result in a chase.

9.4.2 (iii)(g) Chase. Chasing may occur while birds are perched or while flying and involves one bird following another after an aggressive encounter. Chasing may involve female/female, male/male or female/male interactions but no examples of males chasing females were ever seen.

9.4.2 (iv) Appeasement.

9.4.2 (iv)(a) Turn away. The action of turning the head (and, therefore, the bill) away from an aggressive individual in an act of appeasement often results in an aggressive encounter ceasing.

9.4.2 (iv)(b) Withdrawal. The act of withdrawing from an aggressive encounter is an extreme form of turn away and usually results in an aggressive encounter ceasing. Withdrawing may involve moving several steps away from the other bird or it may involve flying some distance from it.

During the breeding season, when a female lands in a tree in which another female is preparing a nest hollow, the intruding female may have to fly several trees away from the occupying female before an aggressive encounter is terminated.

9.4.2 (v) Sexual and other behaviour. Those activities concerned with pair formation, pair bond maintenance and breeding.

9.4.2 (v)(a) Regurgitation bobs. The bird lowers its head and extends its neck. The head is bobbed vigorously up, down and from side to side. This action moves food up from the crop prior to feeding another bird. Regurgitation bobbing is carried out by both males and females prior to feeding their offspring and by males prior to feeding their mates. No adult females were ever seen feeding their mates.

The act of one bird feeding its mate has been called Courtship feeding and it is known to occur in many of the Psittaciformes as well as many other families. In the genus *Agapornis*, only the male feeds the female in several species and the female also feeds the male in other species (Dilger 1960); only the male feeds in the Red-backed Parrots (Willis 1962); in Budgerigars the male usually feeds, but the the female sometimes does so (Brockway 1964c). In the Orange-fronted Parakeet in captivity both sexes feed (Hardy 1963); both sexes feed in the Orange-chinned Parakeet (Power 1967); courtship feeding was not noted in the Quarrion (Zann 1965); in the Hanging Parrots only the males feed (Buckley 1968); and Pidgeon (1970) states that courtship feeding does not occur in the

Galah, while Rowley (pers. comm.) has observed it occasionally in Galahs but maintains it does not form part of their usual repertoire.

9.4.2 (v)(b) Begging crouch. The begging bird crouches down low on the perch and extends its head towards the other bird. While in this position it gives a Begging grate (Vocalizations section) if it is an immature but may not do so if it is an adult female. This posture is used by immature birds towards their parents or by adult females towards their mates.

9.4.2 (v)(c) Food transfer. This takes place when one bird is fed by another. The bird being fed adopts the begging crouch, the two birds touch bills with the feeding bird's bill higher (Figure 66). The bird being fed holds its wings half out from the body and drooped down. The food is transferred by a series of rocking movements accompanied by the feeding A...A...A... (Vocalizations section).

9.4.2 (v)(d) Allopreening. Cullen (1963) proposed the term allopreening for those occasions when it preens the plumage of another bird and Harrison (1965) broadened the terminology to include: Non-reciprocal allopreening - when one bird preens another but is not preened in return; reciprocal allopreening - when one bird preens another and is preened in return in the same bout; and simultaneous preening - when two or more birds preen each other at the same time. This terminology will be followed and refers to such terms as reciprocal preening

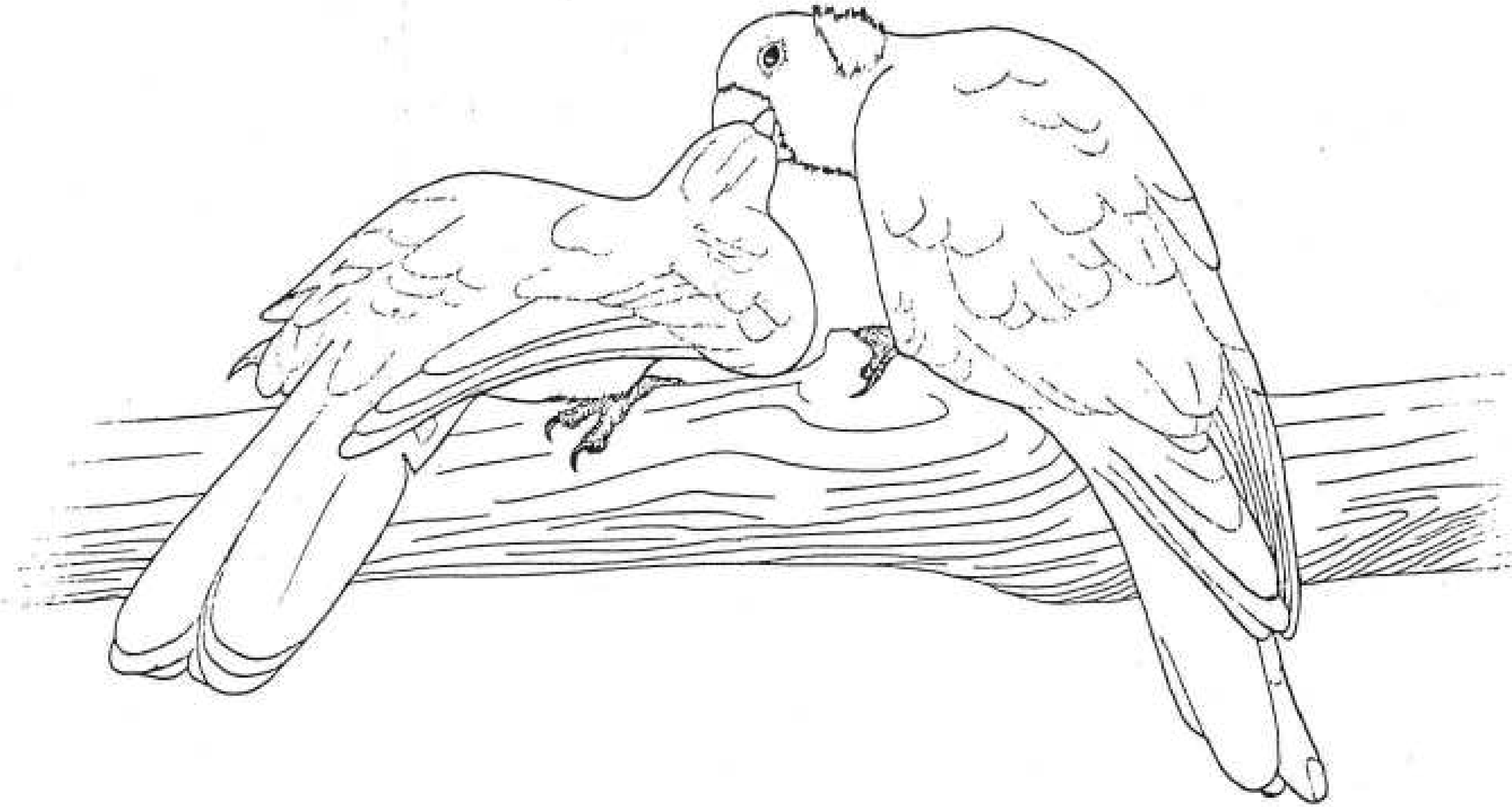


Figure 66. Food transfer.

(Dilger 1960), social or partner preening (Willis 1962) and mutual preening (Hardy 1963, Power 1967).

White-tailed Black Cockatoos allopreen regularly and in populations in the field it has only been seen between members of mated pairs and reciprocal, non-reciprocal and simultaneous allopreening all take place. In aviary populations it usually takes place between pairs and all three forms are also shown. The only deviations from this were bouts of allopreening between two adult females who often allopreened together exhibiting all three forms in addition to allopreening with their mates.

The nibble preening method is used exclusively and the head and neck regions are the most commonly involved (Figure 67) and any attempt to allopreen other areas results in some form of rebuttal.

Either member of a pair may initiate allopreening by offering itself to be allopreened or by beginning to allopreen the other bird. Neither method is always successful.

Adults also allopreen their offspring and in these cases most of the body is covered without any rebuttal. No instance of offspring allopreening their parents was noted - every attempt by the offspring that was observed resulted in a rebuttal.

9.4.2 (v)(e) Offering. This posture is adopted by a bird attempting to initiate allopreening. The head or neck is turned so that the area to be preened is offered to the other individual in such a manner that it is the nearest part and

Figure 67. Allopreening.

is lower than the bill of the other bird (Figure 68). The head and neck feathers are ruffled at the same time. If this offering is not successful the bird may on occasions butt the other bird with its bill gently then resume the offering position.

Squeak displays. These displays all involve the Squeak Call (Vocalizations section) made by males in situations involving females.

9.4.2 (v)(f) Squeak display 1. The male gives a Squeak or a series of Squeaks in the normal perch position. In variations of this display it may give a head bob with each Squeak; fan its tail with each Squeak; or head bob and tail fan with each Squeak.

9.4.2 (v)(g) Squeak display 2. The male lowers its head, fans its tail and bends forward. The body and head are then raised erect while the bird utters the Squeak. In variations on this, the head may be bobbed or waved from side to side as the Squeak is uttered.

9.4.2 (v)(h) Squeak display 3. The male lowers its head, fans its tail, crouches its body and walks towards the female while uttering the Squeak. As it approaches the female, it draws erect standing with its legs extended. The tail is closed as the male returns to the normal perch position or moves away.

Ah-Ah displays. These displays all involve the Ah-Ah call (Vocalizations section) made by males towards females.

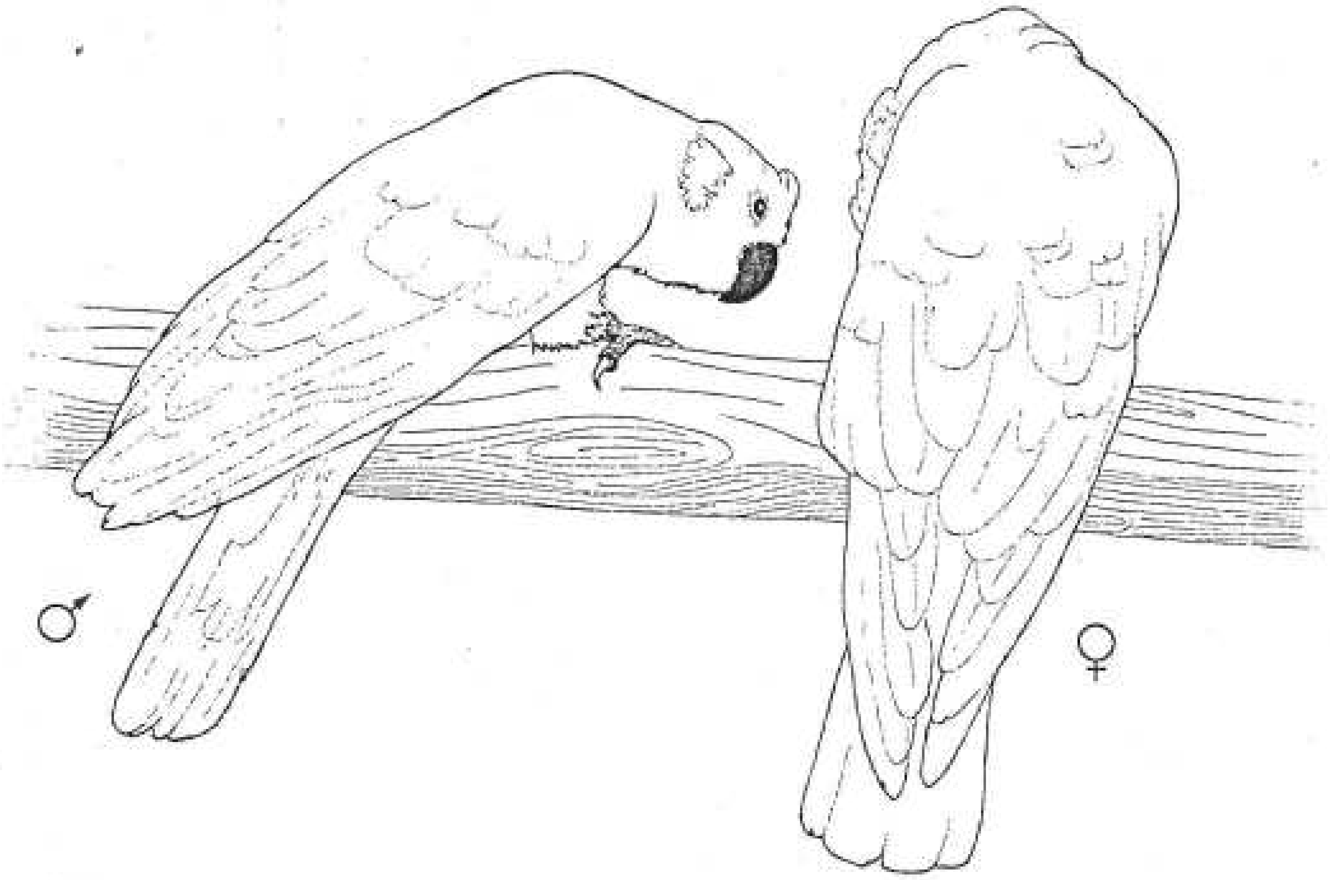


Figure 68. ♂ offering to ♀ who is preening.

9.4.2 (v)(i). Ah-Ah display 1? The male utters a continuous Ah-Ah in the normal perch position. This may be made briefly or it may continue for several minutes. The head is bobbed slightly as each phrase is uttered.

9.4.2 (v)(j) Ah-Ah display 2. The male bobs its head, half fans its tail and rocks backward and forward on the spot uttering a continuous Ah-Ah.

9.4.2 (v)(k) Ah-Ah display 3. The male lowers its head, fans its tail, crouches its body and approaches the female with its head bobbing and uttering a continuous Ah-Ah. As it gets near the female it draws erect with the tail fanned. The male may then resume the normal perch position, or move away quietly or move away in the crouched position with its tail fan closed, bobbing its head and uttering a continuous Ah-Ah.

9.4.2 (v)(l) Head bob and tail fan. Both sexes perform these actions but females do them rarely. The bird bobs its head once or several times, partially fanning its tail with each bob. This may be done in the normal perch position or while walking.

9.4.2 (v)(m) Head wave. This is also performed by both sexes. The head is lowered and waved from side to side once or several times, sometimes with partial tail fan. This may be done in the normal perch position, while walking or in the pre-flight crouch.

9.4.2 (v)(n) Bowing. The head and body are bowed forward then returned to the norml perch position.

Once again it is performed by both sexes.

9.4.2 (v)(o) Wing-head-tail display. The body is bent forward, head lowered, neck extended, wings fully raised and tail fanned. The head may be waved and the wings flapped once or several times. Both sexes perform this display and males occasionally give the Squeak at the same time.

9.4.2 (v)(p) Copulation. The female squats down on the perch and leans forward with the wings held down and out in front of her. The male hops onto the female's back and may adjust itself with several flaps of its wings. It then settles on the back of the female and twists its tail around under the female's tail. The male holds its head down but its wings are held up and back. The pair rock backwards and forwards with the male pushing its cloaca up against the female's. The male may change its tail to the other side of the female's during copulation and on completion it returns to the perch beside the female.

9.4.2 (v)(q) Incubation and brooding posture. Only the females incubate and brood but the posture adopted by the females was not observed as it was not possible during the study to set up the necessary arrangements to observe behaviour inside the hollow.

9.4.2 (vi) Summary of occurrence of the activity patterns in field and aviary populations. All of the activity patterns described with the exception of copulation were seen to be performed by members of the aviary colony. In the field population most of the activity patterns were seen with the exceptions of:

head wave, squeak/chatter with head wave and tail fan, squeak/chatter with head bob, wing-head-tail with squeak, and walking with head twist.

9.5 Vocalizations.

9.5.1 Introduction.

The communication system of the White-tailed Black Cockatoo comprises both auditory and visual displays. (There are no indications that sense of smell plays any part in the communication system.) In the following sections, the auditory displays (vocalizations) are described, illustrated on sonograph tracings and the context in which they are performed is discussed. Several vocalizations are associated with visual displays and these are discussed in the sections relating to those displays of which they form part.

Delacour (1964) noted that 'parrots, usually very gregarious and of high psychological development are the noisiest of all birds. Their voices tend to be harsh screaming, and definitely disagreeable.' While this may be true of most of the cockatoos, the White-tailed Black Cockatoo has a pleasant sounding whistle-like call that carries for considerable distances.

All but one of the vocalizations produced by the White-tailed Black Cockatoo fall into the category of call-notes which are defined by Thorpe (1964) as being mostly monosyllabic or dysyllabic and practically never consisting of more than four or five notes. The majority of their calls are apparently concerned with the co-ordination of the behaviour of other members of the species in situations that are not primarily sexual but concerned with maintenance activities.

9.5.2 Descriptions of calls. In the following catalogue of the vocal repertoire of the White-tailed Black Cockatoo, the calls have been grouped into the categories that appear to cover the context in which they are used and these are:-

9.5.2 (i) Contact calls. Calls that seem to be used in the context of group maintenance.

9.5.2 (ii) Sexual calls. Calls that are made in conjunction with sexual displays.

9.5.2 (iii) Agonistic calls. Calls that are made during encounters of an agonistic nature.

9.5.2 (iv) Begging calls. Calls that are associated with situations involving soliciting food or receiving food from another bird.

9.5.2 (v) Miscellaneous calls. Calls that do not appear to fit into the above categories.

9.5.2 (i) Contact calls.

9.5.2 (i)(a) Wy-lah call. This is by far the most common call made by the birds and may be given by any White-tailed Black Cockatoo. It typically starts at around 1 kHz rising to about 4 kHz, tails off to about 2 kHz and lasts about 0.7 seconds (Figure 69a). It is the loudest of the sounds made by the White-tailed Black Cockatoo and the descriptive name given to the call, wy-lah, is from one of the many Aboriginal words for the black cockatoos. In this case, it is one of the east coast tribes' names for the Yellow-tailed Black Cockatoo

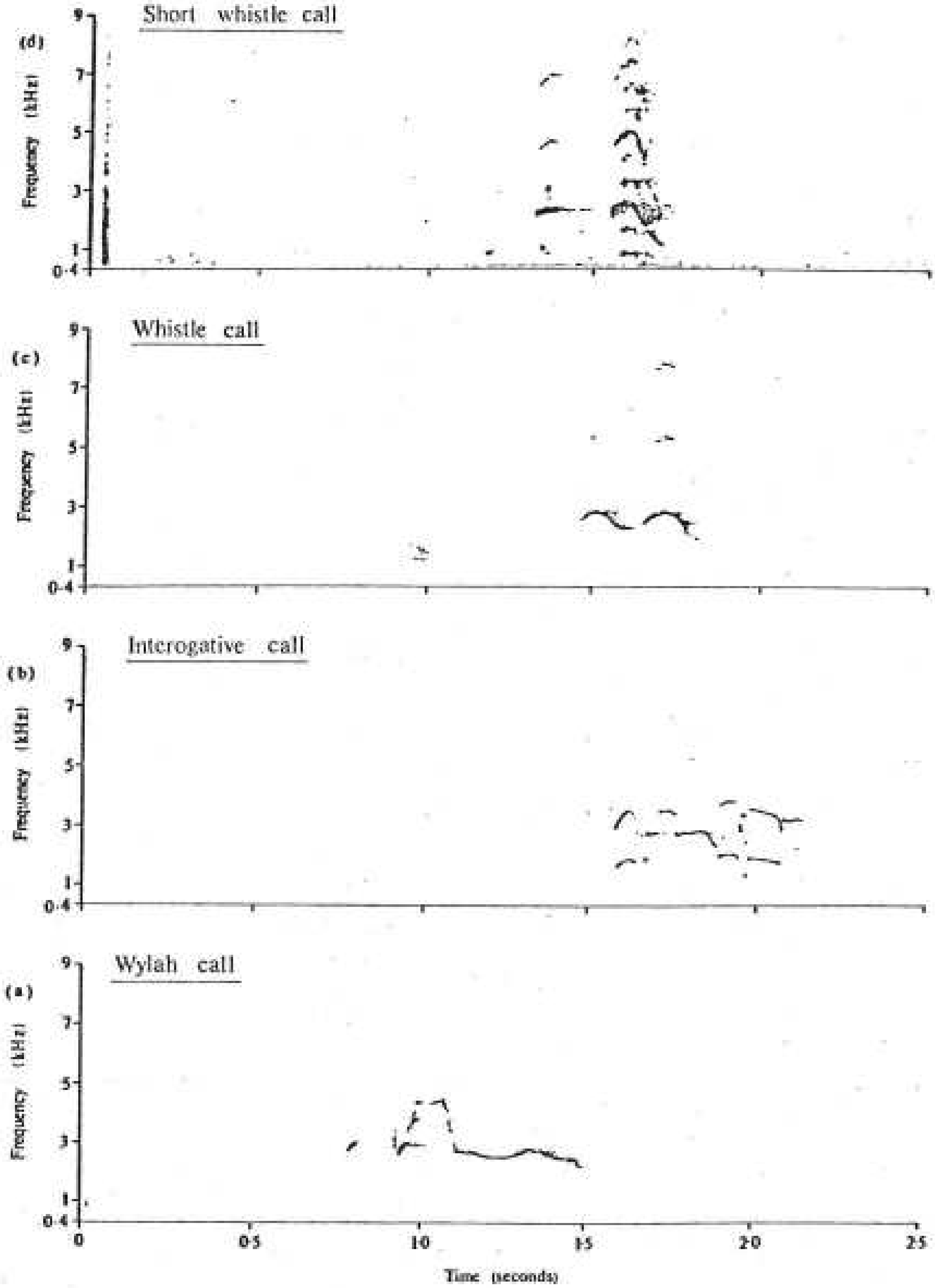

(d)
Short whistle call
(c)
Whistle call
(b)
Interogative call
(a)
Wylah call
Frequency (kHz)
9
7
5
3
1
0·4
0
0·5
1·0
1·5
2·0
2·5
Time (seconds)

Figure 69.

(Rees, no date) but it is also a good description of the sound made by the White-tailed Black Cockatoo.

The wy-lah call is given in a wide variety of situations and there is considerable individual variation in the calls. When flying undisturbed, the members of a group commonly make this call and it is usually heard before the birds themselves are seen. It is a call that is very directional. Birds returning to their nest hollows commonly use the wy-lah call as do stationary groups who hear other birds in the distance. It is commonly used prior to taking off and an individual giving a series of these calls may shorten them until just prior to taking off when a very shortened version is given which may be only three-quarters of the length of the call given when flying. In a series of wy-lah calls, there is usually a distinct break between calls of around 0.4 seconds but they may be given closer together in rapid succession or run together with no break, giving a double wy-lah.

9.5.2 (i)(b) Interrogative call. This call sound like a drawn out wy-lah with an inflection at the end that makes it sound like a question has been asked. The call starts at around 1 kHz, rises to 3 kHz, finishes at 1 kHz and lasts 0.7-0.8 seconds (Figure 69b). It is uttered by both sexes and often occurs in conjunction with the wy-lah call.

9.5.2 (i)(c) Whistle call. This is a dissyllabic call sounding like 'whee-wheee' and has only been heard from adult females. The call has an initial phrase at around 1 kHz followed 0.4-0.5 seconds later by a second phrase at 3 kHz which drops to about 1.5 kHz, the entire call lasting around 0.8 seconds (Figure 69c).

The whistle call may be uttered at various levels ranging from soft to very loud and may be given in juxtaposition with the wy-lah call and is generally given when the bird is not flying. For example, when a group of wild birds flies near caged birds, the caged females may remain on the perch and give many whistle calls and wy-lahs and continue to do so while the wild birds are within hearing.

Caged females appear to be 'restless' when making the whistle call - frequently walking up and down perches and flying round the cage between bouts of calling. While females are involved in a bout of whistle calling, the males are frequently giving the wy-lah call and showing the same sort of 'restlessness'. In the wild, the whistle call may be given prior to a female taking off and flying.

9.5.2 (i)(d) Short whistle call. This is a shortened version of the above whistle call, lasts around 0.6 seconds and has a similar construction as the whistle call (Figure 69d). This call has only been heard from females, is usually of low intensity and is used in the same sort of situations as the whistle call. As a result of the low intensity, it is only audible quite close to the calling bird and the use of this call is not accompanied by the same sort of restlessness that appears to be associated with the whistle call.

9.5.2 (i)(e) Half call. This call has only been heard from males and is a low intensity call. It starts around 1 kHz rising to 3 kHz, tailing off below 1 kHz and is 0.6-0.7 seconds long (Figure 70a).

This call is often uttered in the type of situations where the females give the whistle calls or the short whistle calls.

On occasions during the breeding season when the female is in the nest hollow and the male is nearby, the half call is commonly given by the male while the female is out of sight.

9.5.2 (i)(f) Alert call. This is a monosyllabic call starting around 1 kHz rising to 2 kHz, lasting from 0.5-0.6 seconds and is a harsh sounding scream (Figure 70b).

This call may be given by any individual and is uttered when something is seen or occurs which is unusual or out of place. It was never heard in any other context. For example, if a stationary group of birds see a human approach them, one or several of the birds may give this call. If the intruder is some distance away, the call may be of low intensity but the effect on birds that hear the call is for them to stop what they were doing and look around. If the intruder does not come any closer, the birds may resume what they were doing but may give the alert call occasionally, especially if the intruder alters position. If the intruder comes too close, the alert call may become very loud and insistent with the group flying off shortly after.

On one occasion a group of three birds were seen feeding on a low shrub near a road when a cat ran out of the undergrowth near

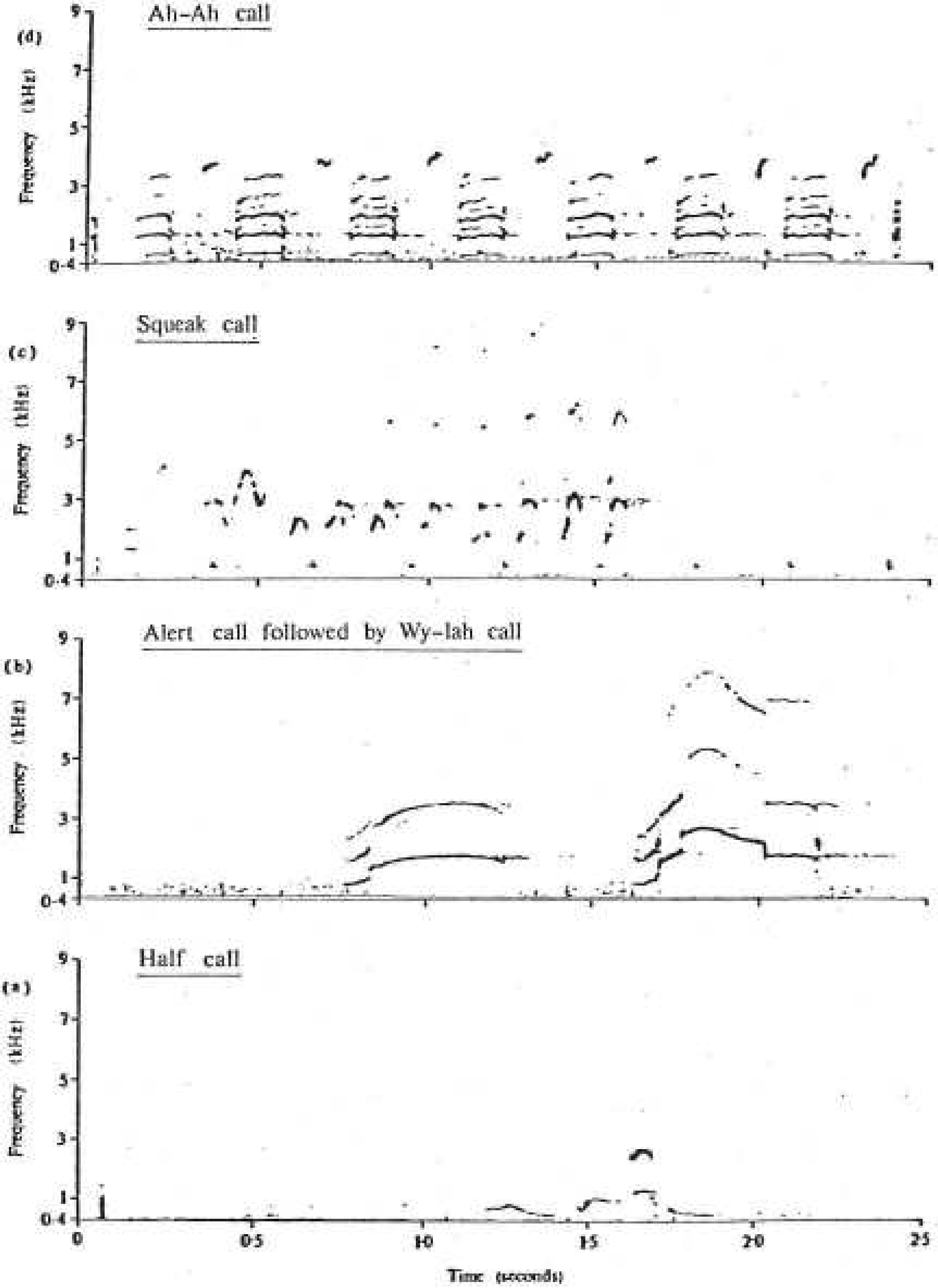

(d)
Ah-Ah call
(c)
Squeak call
(b)
Alert call followed by Wy-lah call
(a)
Half call
Frequency (kHz)
9
7
5
3
1
0·4
0
0·5
1·0
1·5
2·0
2·5
Time (seconds)

Figure 70.

the feeding birds. All three gave very loud alert calls, flying off immediately.

9.5.2 (ii) Sexual calls. Calls in this category are discussed in more detail in the sections on the visual displays of which they form part.

9.5.2 (ii)(a) Squeak. This call is made up of a series of notes rising rapidly from 2 kHz up to 4 kHz and rapidly falling back to 2 kHz (Figure 70c). These notes may be joined in a sequence that can last from one or two notes of about 0.2 seconds up to sequences involving many notes up to several seconds in length.

The squeak calls are made only by adult males in situations involving females. They are the only sounds produced by the White-tailed Black Cockatoo that could be called a type of song, the remainder of sounds being calls of short duration or noise of indefinite structure and length.

9.5.2 (ii)(b) Ah-Ah. These are calls made up of notes of under 1 kHz with several harmonics repeated at corresponding higher frequencies and lasting about 0.1 seconds (Figure 70d). A series of these Ah notes is strung together at 0.1 second intervals to produce a monotonous sequence sounding like Ah-Ah-Ah-Ah ... These sequences vary in length from brief ones of several notes to ones lasting for several minutes.

Once again these calls are only made by adult males and always in situations where they are directed at females.

9.5.2 (iii) Agonistic calls.

9.5.2 (iii)(a) Squeak/chatter. This is a very harsh sounding call made up of frequencies ranging from 0-4 kHz with very little structure to the call (Figure 71a). This call is usually uttered by the male. I have only heard one female utter it and that was in an aviary. The call can be brief or can last for several seconds. It sounds like a squeaky chattering noise and is usually quite loud. The only contexts this call has been heard in are encounters of various types between males and it appears to be of an aggressive nature.

For example, if one male lands near a pair sitting on a perch and makes any approach towards them, the male of the pair may approach him uttering the squeak/chatter.

9.5.2 (iii)(b) Squawk. This is a very harsh sounding noise ranging from 0-3 kHz and ranges from brief squawks lasting for over 1 second and constantly repeated (Figure 71b). The squawk may be of low or very high intensity and may be made by any bird.

It is commonly uttered when nestling or free flying birds are handled by humans and in encounters with other conspecifics in situations where there is conflict over some resource, e.g. nest hollow, food or perch. It is also made during encounters with other species, especially during the breeding season around nest sites.

The squawk has a similar form to the 'scr' call uttered by the Galah (Pidgeon 1970) and is used in similar contexts. The 'scr' is

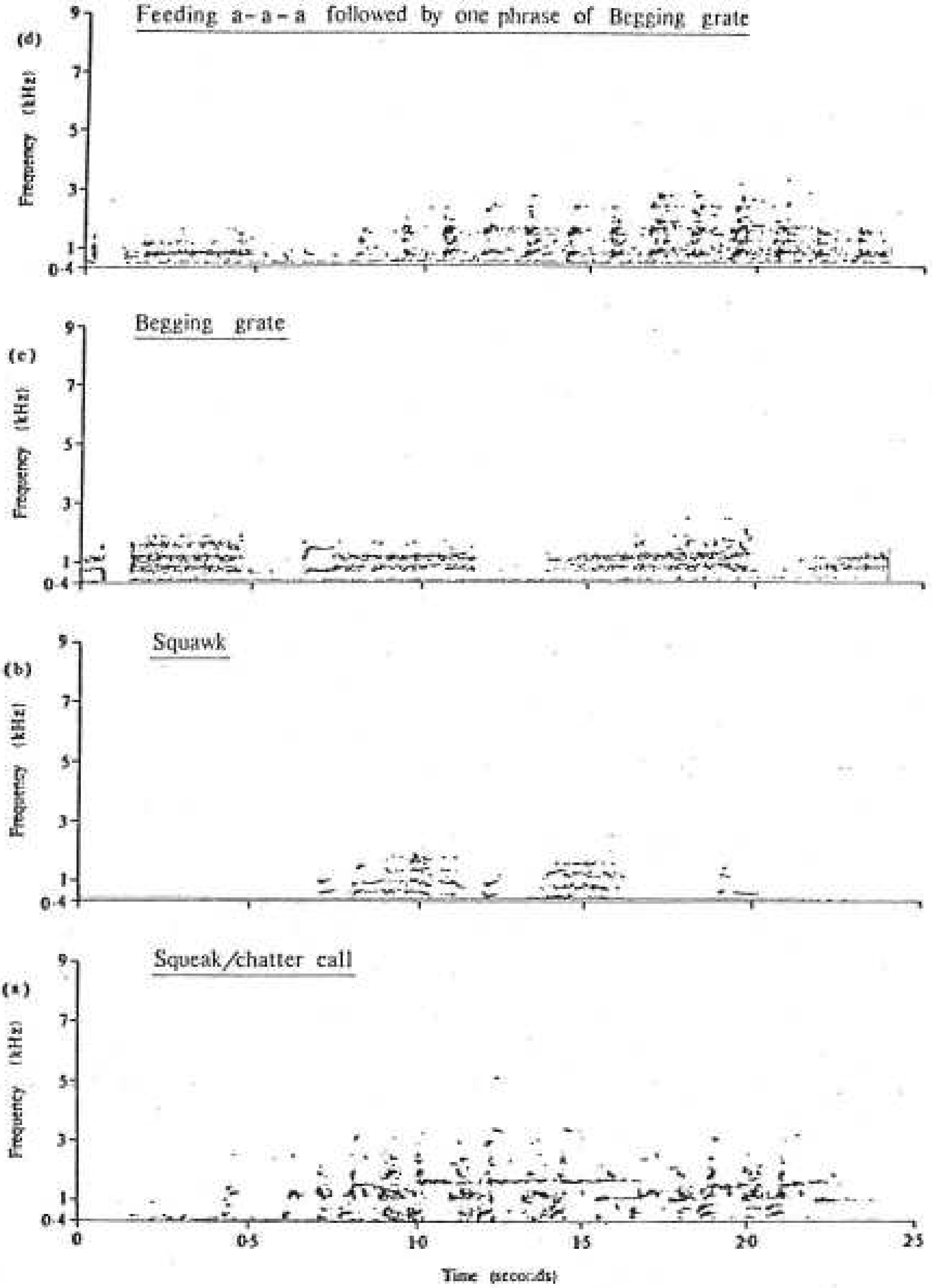

(d)
Feeding a-a-a followed by one phrase of Begging grate
(c)
Begging grate
(b)
Squawk
(a)
Squeak/chatter call
Frequency (kHz)
9
7
5
3
1
0·4
0
0·5
1·0
1·5
2·0
2·5
Time (seconds)

Figure 71.

'a noisy screeching sound of indefinite duration' which is uttered when a Galah is under stress, when hovering over a predator and during agonistic encounters between other Galahs.

9.5.2 (iv) Begging calls.

9.5.2 (iv)(a) Begging grate. The begging grate is a noise of little structure from 0-3 kHz with most of the energy round 1 kHz (Figure 71c). It is usually a continuous noise made up of notes of 0.4-0.6 seconds but they can be longer and the intensity varies from low brief grates to loud harsh continuous grates that may go on for minutes.

The begging grate is made by nestlings and immature birds prior to their being fed by their parents. The sight or sound of the parents when the bird is hungry appears to release the begging grate and the bird continues making it until it has had sufficient food or until the adults leave its presence.

The begging grate is also made by adult females during the breeding season when the male returns to the nest area while the female is incubating or brooding. The females do not always make the begging grate prior to being fed but in most cases they do.

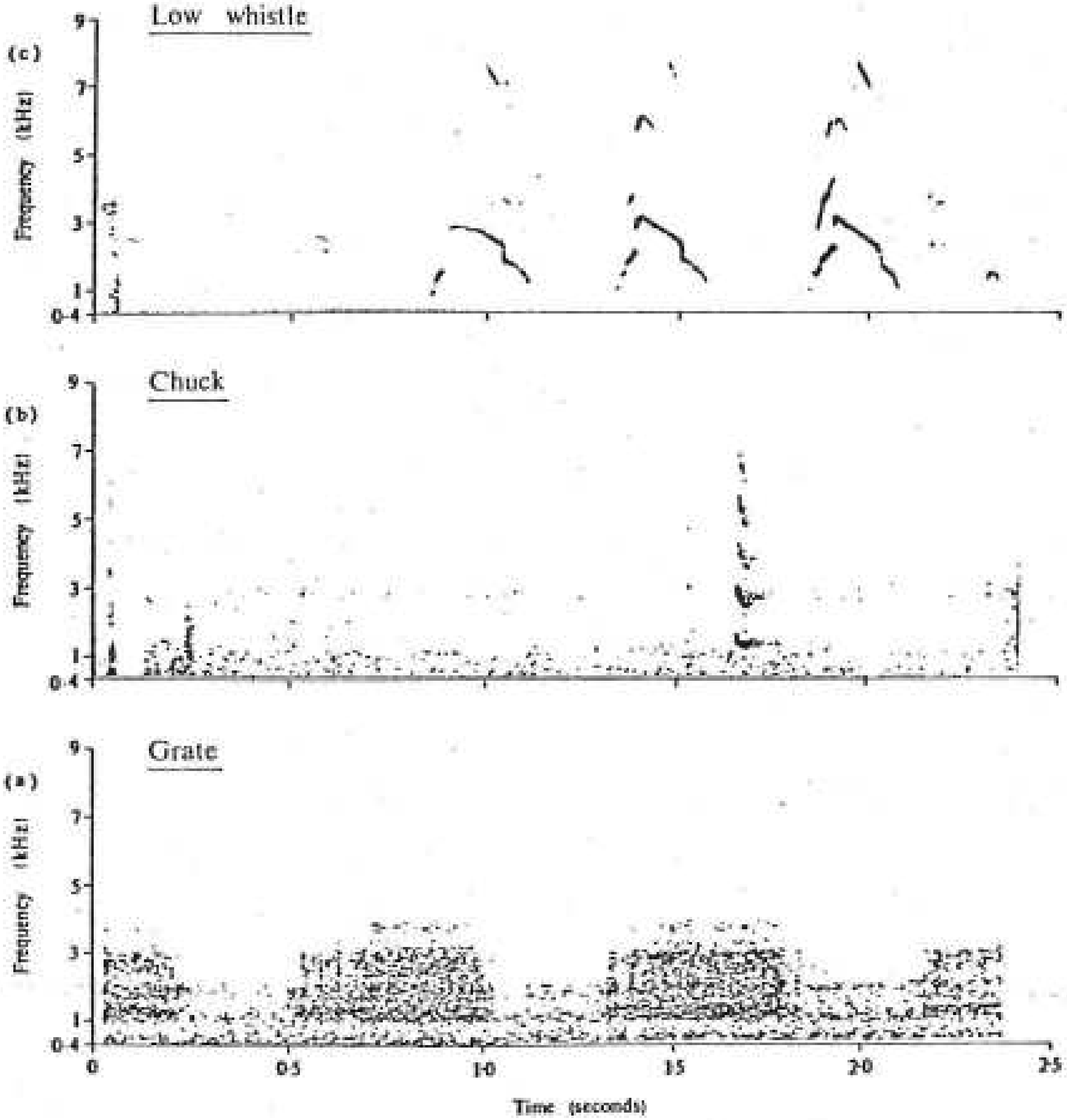
9.5.2 (iv)(b) Feeding A..A..A. This is a noise sounding like 'A..A..A..A..A..' and consists of a number of syllables comprising frequency bands at 1, 2 and 3 kHz (Figure 71d). The syllables are about 0.06 seconds long and 0.07 seconds apart. The sound is produced when one bird is being fed by another. When food is transferred, a jerking motion is used and each 'A' syllable coincides with a downward jerk. The action involved in transferring food may result in the production of this noise as a mechanical by-product. Immature White-tailed Black Cockatoos that are spoon-fed during hand rearing also produce this noise when being fed as the food is forced into the crop.

Galahs (Pidgeon 1970) and Port Lincoln Parrots (pers. obs.) also produce a similar noise when immature birds are fed by their parents.

9.5.2 (v) Miscellaneous calls.

9.5.2 (v)(a) Grate. This is a grating or buzzing noise that has virtually no form but a continuous range of noise from 1-6 kHz (Figure 72a). The syllables last for about one second with varying periods as low as 0.04 seconds between. Bouts of grating can go on for long periods and are made by immature birds up to independence from their parents. Adult birds and birds no longer dependent on their parents do not seem to utter the grate and it was never heard from any of the birds caged at Helena Valley until one pair bred successfully and fledged a young. This fledgling uttered the grate constantly until it was about 9 months old, by which time, in the wild, it would have become independent of its parents.

The grate is commonly heard from immature birds in groups in a variety of contexts. Immature birds in feeding groups, in groups settled in trees and in flying groups have uttered the grate. The immature birds producing the grate are usually near their parents but



(c)
Low whistle
(b)
Chuck
(a)
Grate
Frequency (kHz)
9
7
5
3
1
0·4
0
0·5
1·0
1·5
2·0
2·5
Time (seconds)

Figure 72.

the parents do not appear to react to it in any way unlike the begging grate which usually elicits some response from them.

9.5.2 (v)(b) Chuck. This is a very low intensity call that does sound like 'chuck'. It is about 0.04 seconds long and consists of two pulses, one at just over 1 kHz and the other just under 3 kHz (Figure 72b). Because of the low intensity of the chuck, it is only audible quite close to the bird producing it. It is uttered by both sexes and usually when the birds are alone.

For example, a female who is incubating may climb up and sit in the entrance to the hollow and go 'chuck' occasionally. Birds isolated in cages occasionally produce this call.

9.5.2 (v)(c) Low whistle. This is a very low intensity call that has not been heard often. It consists of notes from 1 kHz rising to 3 kHz, dropping to 1 kHz and lasting around 0.1 seconds (Figure 72c). There are usually several notes given and has only been heard from adult females and always in situations when they are alone.

In both the chuck and the low whistle, the low intensity and solitary situations in which it is uttered seems to indicate that neither are contact calls. The functions of both calls are unclear and Rowley (1973) noted that several of the Corvids had several calls for which he had no explanation. Here again, they were delivered usually when the birds were alone and idle.

9.5.3 Individual recognition. Recognition of one individual by another has been observed in many species and appears to be well developed in social species. Tinbergen (1953), studying the Herring Gull (Larus argentatus), noted that individuals could recognize their mates and neighbours from both auditory and visual cues. Weedon and Falls (1959) demonstrated that male Ovenbirds (Seirus aurocapillus) can distinguish between songs of different individuals of their species and can recognize songs of particular individuals (their neighbours). Nelson (1965) noted that in the Gannet (Sula bassana) individual differences in voice enable individuals to recognize mates and neighbours as they fly in. He also noted that chicks recognize the voices of their parents. Stevenson et al. (1970) demonstrated that chicks of Common Terns (Sterna hirundo) recognize their parents call and react to it by gaping and cheeping - reactions they did not show to calls from other individuals. Jarvis (1971) recorded that in the South African Gannet (Sula capensis) it was apparent that many birds could recognize their parents' voices, although he did record a number of instances where a mistake was made.

The White-tailed Black Cockatoo, with its long-lasting pair bonds and relatively long period of dependence of the young on the parents, could be expected to show recognition of individuals. Records were made during hide and incidental observation periods to see if the birds possessed this faculty. It soon became apparent that birds did recognize different individuals and they did so from both auditory and visual cues.

At Coomallo Creek in 1974, there were four active nests in the immediate vicinity of the hide, and early in the breeding season, there were females present in each of these nest hollows, either incubating eggs or brooding small nestlings. This particular area was located near the centre of the study area and there was usually a lot of cockatoo activity around it, especially at those times when the males usually returned to feed the females. There was a watering point and roosting area nearby and this resulted in more activity around the area than there would have been in a more isolated patch of woodland.

As mentioned earlier, when birds were flying, they commonly gave the wy-lah call and it was usually given when returning to the area of the nest. Despite constant exposure to wy-lah calls from many different directions, the females remained in their hollows. On hearing one particular individual calling, the female would leave the hollow and fly directly towards the incoming bird, or call and fly to a nearby tree and wait for the bird to land near her. On every occasion that this was observed the incoming bird the female reacted to, was her mate. In 1974, of 30 instances where a male was observed returning to the area of the nest hollow, calling as he flew, in 28 of these the female left the hollow and joined the male as it was flying in or shortly after it landed. In the remaining 2 cases the female did not leave the hollow immediately but did subsequently leave and join the male.

Large nestlings were also able to recognize their parents' calls and this was observed on many occasions. Nestlings have started giving loud insistent begging grates and wy-lah calls from inside the hollow on hearing their parents calling some distance away and under the same conditions that females were seen to recognize their mates' calls.

There are other examples away from nesting sites where this type of recognition was demonstrated by both males and females. For example, lone birds were heard calling as they flew in to join groups of birds feeding. Individuals were seen to leave these groups and fly out to join the incoming bird. On each occasion in which the identities of the birds were known, the birds were paired.

There were many examples of identification involving auditory cues but very few involving visual cues only. The birds were able to recognize individuals from visual cues only and this was illustrated several times. On one occasion at Coomallo Creek, a group of 12 birds flew in and settled in a tree about 30 metres from nest hollow 6 in which there was a female on eggs. The male from 6 was in the group but the female did not leave the hollow when they flew in, although the birds were calling as they flew in and settled. Once the group had settled they sat quietly with very little activity. About 20 minutes later, female 6 left the hollow quietly and flew directly to the group, landing beside her mate. She was fed by him soon after.

One advantage in being able to recognize an individual's call is the saving of energy as a result of reacting only to the correct individual. The female need only cease incubating when the male is approaching the area of the nest hollow. If she were not able to identify the male from its call, she may be bobbing in and out of the hollow every time she heard a wy-lah call, wasting energy and not incubating constantly.

In the case of the nestlings, they only react when the parents are near and the fact that there is a young bird in the hollow is only advertised at the time when the adults are around to defend it.

In view of the fact that one individual is able to recognise another from its call an analysis of the wy-lah call was carried out to determine what parameters show sufficient variation between individuals to make this recognition possible.

The calls of eight adult females and six adult males were recorded at Helena Valley by isolating each bird in a cage 100 metres from the nearest birds. A Beyer M100 microphone was placed near the cage and a Sony TC800B recorder was used to record the calls. A recording was made of each bird from 1700 to 1830 hours for three days. Males were more vocal than females during this period (mean 54 [range 46-112] calls compared with 32 [13-45] by females).

Twenty wy-lah calls were selected from each individual (all wy-lah calls were used from those that produced less than 20) for further analysis. Each wy-lah was then recorded on a sonograph using the narrow-band filter (45 kHz) and a sonograph tracing produced. Each wy-lah was subdivided into four segments and from these four segments (shown on Figure 16b) nine parameters were chosen for measurement. These were: the total length of the call (seconds); the length of each segment (secs); the commencing frequency of segments "A", "C" and "D" in kHz and the peak frequency of segment "B" (kHz) which is also the peak frequency of the call.

In all, 140 wy-lah calls from females and 120 from males were analysed and the mean measurement and standard deviation for each parameter from each individual are given in Table 49a and b. Also given on these tables are the coefficients of variation (standard deviation divided by the mean expressed as a percentage) for each parameter. An analysis of variation was carried out on each parameter for both sexes and there was a significant difference between individuals within each sex in every parameter.

For each parameter, an analysis was carried out to compare each mean with the one below it in value and the results of this analysis are shown in Tables 50a and b. These results show that each individual's values differ in relation to other individuals throughout the nine parameters. For example, female 052 has the longest call but the length of segment "D" is among the shortest in the sample. Similarly, male C-50 has a call among the longest in the sample but the length of segment "B" is the shortest.

The overall mean values for each parameter for all of the female and male wy-lah calls were then compared and the results of this analysis are shown on Table 51. There was no significant difference in the total length of the wy-lah calls between the sexes but there were significant differences between the sexes in each of the other eight parameters.

TABLE 49a

Quantitative treatment of 9 parameters of the Wy-lah call from 8 individual adult females

Female	No. of Calls	Total duration (secs) *	Segment "A" duration*	Segment "A" Start† frequency	Segment "B" duration*	Segment "B" Top† frequency	Segment "C" duration*	Segment "C" Start† frequency	Segment "D" duration*	Segment "D" Start† frequency
044	20	.71±.03	.14±.01	.78±.04	.16±.01	4.31±.08	.34±.02	2.45±.06	.08±.01	1.68±.07
105	20	.69±.04	.14±.01	.81±.04	.16±.02	4.33±.07	.33±.02	2.43±.05	.07±.01	1.64±.06
065	20	.69±.02	.15±.01	.80±.06	.15±.01	3.72±.11	.31±.02	2.46±.09	.08±.01	1.71±.06
052	13	.76±.04	.15±.01	.85±.05	.16±.01	4.42±.11	.34±.03	2.60±.05	.08±.01	1.82±.07
320	14	.59±.03	.04±.01	1.24±.22	.23±.02	3.78±.20	.16±.01	2.44±.06	.17±.01	1.76±.05
225	20	.56±.04	.02±.01	1.19±.21	.23±.04	4.00±.12	.14±.02	2.41±.03	.16±.01	1.76±.05
167	13	.55±.03	.07±.01	.81±.12	.04±.01	3.05±.23	.22±.03	2.48±.04	.22±.02	1.81±.06
C-04	20	.58±.05	.09±.02	.85±.08	.10±.02	3.63±.06	.19±.03	2.65±.08	.20±.02	1.83±.05
Overall	140	.64±.08	.10±.05	.91±.21	.16±.06	3.93±.42	.26±.08	2.49±.10	.13±.06	1.74±.09

* durations are in seconds
† frequencies are in kHz
Values are means ± standard deviation

Coefficient of variation for each parameter from each individual [Coefficient of variation is standard deviation divided by the mean and expressed as a percentage $(\frac{s}{\bar{x}} \times 100)$].

Female	No.	Total duration	"A" duration	"A" st. freq.	"B" duration	"B" top freq.	"C" duration	"C" st. freq.	"D" duration	"D" st. freq.
044	20	4	7	5	6	2	6	2	13	4
105	20	6	7	5	13	2	6	2	14	4
065	20	3	7	8	7	3	6	4	13	4
052	13	5	7	6	6	2	9	2	13	4
320	14	5	25	18	9	5	6	2	6	3
225	20	7	50	18	17	3	14	1	6	3
167	13	5	14	15	25	8	14	2	9	3
C-04	20	9	22	9	20	2	16	3	10	3
Overall	140	13	50	23	38	11	31	4	46	5

TABLE 49b

Quantitative treatment of 9 parameters of the Wy-lah call from 6 individual males

Male	No. of Calls	Total duration (seconds)	Segment "A" duration	Segment "A" Start frequency	Segment "B" duration	Segment "B" Top frequency	Segment "C" duration	Segment "C" Start frequency	Segment "D" duration	Segment "D" Start frequency
029	20	.76±.03	.14±.01	.82±.10	.10±.01	3.48±.12	.16±.02	2.47±.14	.37±.02	1.87±.10
C-03	20	.58±.03	.14±.01	.82±.10	.13±.02	3.54±.14	.16±.02	2.64±.11	.16±.01	1.88±.06
C-50	20	.73±.03	.11±.02	1.15±.11	.06±.01	2.88±.20	.29±.03	2.59±.11	.27±.04	1.98±.07
103	20	.57±.02	.16±.01	.76±.08	.09±.01	3.34±.09	.14±.01	2.68±.07	.19±.01	1.81±.05
C-48	20	.64±.03	.14±.02	.87±.07	.23±.02	3.78±.12	.12±.01	2.59±.08	.16±.01	1.85±.05
321	20	.64±.04	.15±.01	.74±.05	.19±.01	3.92±.09	.11±.01	2.62±.10	.19±.02	1.92±.04
Overall	120	.65±.08	.14±.02	.82±.18	.13±.06	3.49±.35	.16±.06	2.60±.12	.22±.08	1.88±.08

Coefficient of variation for each parameter from each individual

Male	No.	Total duration	Segment "A" duration	Segment "A" frequency	Segment "B" duration	Segment "B" frequency	Segment "C" duration	Segment "C" frequency	Segment "D" duration	Segment "D" frequency
029	20	4	8	12	9	3	11	6	6	6
C-03	20	6	7	11	19	4	13	4	8	3
C-50	20	5	18	10	12	7	12	4	16	4
103	20	3	8	11	9	3	9	3	7	3
C-48	20	5	16	9	9	3	10	3	8	3
321	20	6	8	7	5	2	9	4	11	2
Overall	120	12	15	22	46	10	39	5	36	4

TABLE 50a

Differences between individual females in the 9 parameters

TOTAL DURATION OF CALL		052	>	044	≡	105	≡	065	>	320	≡	C-04	≡	225	≡	167		
Segment	Duration	052	≡	065	>	044	≡	105	>	C-04	>	167	>	320	>	225		
"A"	Start frequency	320	≡	225	>	052	≡	C-04	≡	167	≡	105	≡	065	≡	044		
Segment	Duration	225	≡	320	>	052	>	044	≡	105	≡	065	>	C-04	>	167		
"B"	Top frequency	052	≡	105	≡	044	>	225	>	320	≡	065	≡	C-04	>	167		
Segment	Duration	052	≡	044	≡	105	≡	065	>	167	>	C-04	>	320	>	225		
"C"	Start frequency	C-04	≡	052	>	167	≡	065	≡	044	≡	320	≡	105	≡	225		
Segment	Duration	167	>	C-04	>	320	≡	225	>	065	≡	052	≡	044	≡	105		
"D"	Start frequency	C-04	≡	052	≡	167	≡	320	≡	225	≡	065	≡	044	≡	105		

Maximum Values ——————————→ Minimum Values

≡ No Significant Difference

> Significant Difference (.01> P).

TABLE 50b

Differences between individual males in the 9 parameters

TOTAL DURATION OF CALL		029	>	C-50	>	C-48	≡	321	>	C-03	≡	103
Segment	Duration	103	≡	321	≡	C-03	≡	029	≡	C-48	>	C-50
"A"	Start frequency	C-50	>	029	≡	C-03	≡	103	≡	321	>	C-48
Segment	Duration	C-48	>	321	>	C-03	>	029	≡	103	>	C-50
"B"	Top frequency	321	>	C-48	>	C-03	≡	029	>	103	>	C-03
Segment	Duration	C-50	>	029	>	C-03	>	103	>	C-48	≡	321
"C"	Start frequency	103	≡	C-03	≡	321	≡	C-50	≡	C-48	>	029
Segment	Duration	029	>	C-50	>	321	≡	103	≡	C-48	≡	C-03
"D"	Start frequency	C-50	≡	321	≡	C-03	≡	029	≡	C-48	≡	103

Maximum Values ——————→ Minimum Values

≡ No Significant Difference between means

> Significant Difference (.01 > P).

TABLE 51

Comparisons between mean values for ♀♀ and ♂♂ of 9 parameters

		♀♀	♂♂	t	Significance	Coefficient of Variation ♀♀	Coefficient of Variation ♂♂
TOTAL DURATION OF CALL		0.64	0.65	0.91	NS	13	12
Segment	Duration	0.10	0.14	7.59	.001 > P	50	15
"A"	Start frequency	0.91	0.82	3.62	.002 > P >.001	23	22
Segment	Duration	0.16	0.13	3.15	.002 > P >.001	38	46
"B"	Top frequency	3.93	3.49	9.18	.001 > P	11	10
Segment	Duration	0.26	0.16	10.32	.001 > P	31	39
"C"	Start frequency	2.49	2.60	7.95	.001 > P	4	5
Segment	Duration	0.13	0.22	10.38	.001 > P	46	36
"D"	Start frequency	1.74	1.88	13.52	.001 > P	5	4

No. calls analysed	140	120
No. individuals	8	6

Within sexes the coefficients of variation are lowest in the segment frequencies and total length of call and highest in the segment lengths. This would seem to indicate that it is the discrimination of time by which one individual identifies another rather than the discrimination of frequency. Rooke and Knight (1977), in a discussion on sound location, reviewed the literature on avian discrimination of frequency and time. They noted that "birds and man may have comparable abilities to detect changes in frequency but avian discrimination of time is some 10 to 100 times better than man's with the latter figure more likely." The figure they suggested for birds was 0.5 msec (.0005 seconds). The difference in length of segments within and between individuals exceeds this figure many times and is well within the bird's capacity of discrimination.

Hutchinson _et. al_ (1968) using one call from each of 40 Sandwich Terns (_Sterna sandvicensis_) and Berger and Ligon (1977) with one call from 12 Pinion Jays (_Gymnorhinus cyanocephalus_) found that the coefficient of variation for the total length of the calls was lower but that certain parameters had much higher coefficient of variation. Both studies concluded that those parameters with the higher variability possibly allow auditory recognition of one individual by another and that those parameters with low variability were possibly parameters that were associated with species identificatión.

9.5.4 _Discussion of vocalizations._ Within the White-tailed Black Cockatoo there are 15 different groups of calls but these are probably not the full range used by the birds. Within each group there is certain to be a range of variations of each call within one individual bird's repertoire and each variation may convey a different meaning depending on mood and context. Cameron (1968) in the discussion on her study of the Red-backed Parrot (Psephotus haematonotus) noted that the most commonly uttered signals lack specificity of context and she suggested that they fulfil several functions. This is certainly true of the White-tailed Black Cockatoo as far as the wy-lah call is concerned. One particular wy-lah may convey a different meaning to a slightly altered wy-lah given in the same context. For example, a bird, sitting in a tree with another bird, may give the wy-lah call several times before flying off. The shorter the wy-lah is and the more often it is repeated before flying, the greater the probability that the remaining bird will take off and follow.

There are relatively detailed accounts of the vocal repertoire of six species of parrot given in the literature. These are: Brereton (1963, 1971) and Brereton and Pidgeon (1966) on the Eastern Rosella (Platycercus eximius) in which initially 19 calls were determined then later increased to 25; Brockway (1964a and b) who distinguished eight calls in the Budgerygah; Zann (1965) who distinguished seven calls in the Quarrion; Power (1966) who distinguished nine calls in the Orange-chinned Parakeet; Cameron (1968) who described 15 vocal signals in the Red-backed Parrot; and Pidgeon (1970) who found nine distinct calls with a number of variations in the Galah.

Of all of these studies, including the present one on the White-tailed Black Cockatoo, only Cameron's work was entirely devoted to vocal communications. The remainder were part of broader studies on behaviour, ecology or both. Cameron notes that her findings of 15 described calls are probably not the full range of calls as she did not work for a full year on the birds and some of the breeding repertoire may have been missed.

In social birds like the parrots, vocal communication has an important role in co-ordinating group activities. As a result of individual variations in calls, the study of vocal communication is very time consuming and as a consequence, results obtained from other broader studies may be limited and tend to understate the complexity of the system.

Rowley (1974) noted that long-lived birds with long-lasting pair bonds that pass the non-breeding season together may not require elaborate courtship displays as the onset of breeding does not pose behavioural problems that arise with species that only pair for the reproductive season. This point is borne out by the paucity of vocal signals in the White-tailed Black Cockatoo associated with sexual situations. Only two of the 12 groupings of calls that may be assigned to a functional category, are used exclusively in a sexual category. The remainder are used in group maintenance and co-ordinating categories.

9.6 Quantitative study of behaviour. The study of birds in the field revealed that there were problems associated with collection of data. The birds were mobile, easily startled and hard to follow because of the nature of the country over which they foraged. The only point where continuous observation could be made was around the nest site from a hide. At other locations and during the non-breeding season they were never in one spot long enough to follow up known individuals for long periods. In an attempt to overcome this and to try to clarify some questions raised by the field study, aviary experiments were conducted and comparisons made between results gathered from the field populations and results from aviary populations.

9.6.1 Which sex was most suitable for a study of behaviour? Observations made in the field had shown that the birds were more active in the early morning and late afternoon. It also seemed that males appeared to perform more displays oriented towards the female than vice versa. In order to establish if birds held in aviaries showed similar activity patterns to those shown by wild birds a male and female were observed in the Big Aviary from 0940 to dark and from dawn to 0940 the following day. The birds had been in the aviary for several months prior to the observations.

The birds' actions were scored in hourly units. In addition, the length of each feeding bout was noted. The number of times various actions were performed at different times of the day are shown on Table 52. Actions associated with locomotion have been excluded and autopreening, scratching, stretching and shaking have all been grouped under maintenance. In each category the number given is the number of bouts of that action in the time period, rather than the number of times an individual action was performed.

TABLE 52

Number of times various actions were performed at different times during a day by a male and female in the Big Aviary.

Action	Male						Female					
	0640-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800	0640-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800
Calling	10	2	1			9	1	1				2
Chewing	4	2	3		2	9	5	3	1		3	8
Bill face/ sqk.	1		1				1		1			
Wht.	11					7						1
SD1	16	1	2			2						
SD2	1				2							
Ah-Ah 1	1	2				3						
Ah-Ah 2						2						
Rbs		3	2			1						
Feed another or be fed		2						2				
Head bob			2									
Allopreen			2	1					2	1		
Totals	44	12	13	1	4	33	7	6	4	1	3	11
Maintenance	0	3	10	4	0	1	0	6	7	4	0	1

Total male activities scored: 125

Total female activities scored: 50

For example, one bout of preening may have occupied ten minutes and several areas may have been preened, but it would score as one bout of maintenance.

The male performed 2.5 times as many bouts of activity as the female and confirmed what appeared to be true of wild birds. Both birds were more active in the early morning and late afternoon and maintenance activities tended to occur during the periods when the birds were less active.

The time spent feeding is shown for each bird on Table 53. The male spent 36 minutes in 17 bouts (mean 2.1 minutes per bout; range 1-8 minutes) and the female spent 29 minutes in 15 bouts (mean 1.9; range 1-8). Both birds fed prior to 0800 and did not recommence feeding until after 1400. The indications from this small sample were that the males would be better subjects for a study of behaviour because they had a broader repertoire of displays than the females.

The early morning and the late afternoon were found to be the most productive periods for observation as the birds tend to be more active then. This was also true of wild birds and it appeared that the daily cycle of birds in the aviary was essentially similar to that displayed by wild birds with one very important difference. Aviary birds did not have to commute any distance to look for food. Food was available in one location and total time spent feeding was brief - around half an hour. Wild birds have to search for their food and then to gather it. With very few exceptions, food was not concentrated and feeding took much longer than in

TABLE 53

Time (minutes) spent feeding by an aviary male
and female. Number of bouts indicated in brackets.

	0640-0800	0800-1000	1000-1200	1200-1400	1400-1600	1600-1800	Total
Male	16 (5)	1 (1)	0	0	12 (7)	7 (4)	36 (17)
Female	15 (5)	1 (1)	0	0	5 (4)	8 (5)	29 (15)

aviaries. This extra time available to aviary birds may have resulted in some modification in their behaviour.

9.6.2 Sequential analysis of the behaviour of males.

9.6.2 (i) Introduction. In common with many other animals, the behavioural activities of White-tailed Black Cockatoos were not randomly distributed in time or in association with each other. It was obvious that some activities often occurred together and that some, as a result, may have been causally linked. While causal linkage is very difficult to investigate and prove, it is possible to investigate the temporal association of displays by using sequential analyses. These techniques have been used by a number of workers for a range of studies from specific analyses of a particular behaviour of one individual through studies on a wide variety of behaviours by many individuals (e.g. reproductive behaviour of Bitterlings [Wiepkema, 1961]; maintenance, feeding and locomotion in Magpie Geese [Davies, 1963]; agonistic behaviour of Great Tits [Blurton Jones, 1968]; maintenance behaviour in Skylarks [Delius, 1969]; behaviour of bicolor Damselfish [Myrberg, 1972]; behaviour in isolated male Zebra Finches [Slater and Ollason, 1972]; and agonistic and sexual behaviour of Cyprinodent Fish [Ewing and Evans, 1973]). The rationale behind these techniques and the methods used are well set out in several of these papers as are some of the limitations.

In order to give some understanding of the temporal association of the displays of male White-tailed Black Cockatoos sequence analyses were carried out. Observations of males from field and aviary populations were analysed and sequences of behavioural units were entered into a table for the relevant population; the tables consisted of columns and rows with behavioural units listed in the same order in both, so that each unit was equidistant from the upper left hand corner of the table. For example, normal perch position occupies space five in both column and row lists. The list of units down the side of the table (column) were the preceding actions and the units along the top (row) were the following actions. The tables were constructed by entering the figure for the total number of times one action was followed by another. In the calculations based on these figures, the number of times one action followed itself (i.e. was repeated) was ignored. As Davies (loc. cit.) explained "repetitive actions were considered as single acts and each individual action in a repetitive sequence was assumed to express the same mood".

Using methods fully explained by Davies (loc. cit.) in his appendix, expected values for each cell in the table were calculated. Any difference between the observed and expected values was considered significant if it amounted to more than three times the square root of the expected value. Observed values significantly less than expected were considered to indicate a negative correlation (i.e. that action followed less often then would be expected on a random basis) and observed values significantly greater than expected were considered positively correlated.

The tables for both populations were summarized so that only the significant positive and negative correlations were indicated. These summaries are shown in Tables 54 and 55. The column and row totals are shown and the column total for one behavioural unit often differs from the row total for the same behaviour. This

TABLE 34

Summary of sequential contiguity table for field males. The table was constructed from 93 hours observations of 11 males. The + indicate significant positive correlation, and - indicate significant negative correlation.

Following action Preceding action	Drinking	Feeding	Pre-flight crouch	Flying	Normal perch	Walking	Head wave	Squeak/chatter	PTC with sq/ch	Sq/ch with head wave tail fan	Sq/ch with head bob	Bill face	Bill face with gape and squeak	Scratching	Shaking	Stretching	Autopreen	Chewing	Offering	Allopreen	Be allopreened	Move to	Move away	PTC with head wave tail fan	Regurgitation bobs	Bill touch	Feed another	Walk with head bob	Walk with head wave tail fan	Squeak Display 1	SD 1 with head bob tail fan	Squeak Display 2	Squeak Display 3	Ah-Ah 1	Ah-Ah 2	Ah-Ah 3	Copulation	Head bob	Bowing	Tail fan	Head bob with tail fan	Wing/head/tail	WHT with squeak	Call	Half-call	Chuck	Chuckle	Walk with twist	Into hollow	Leave hollow	Row total observations
Drinking			+																																																3
Feeding			+																																																4
Pre-flight crouch				+	-	-											-					-	-		-		-			-				-										-	-						560
Flying		+	-		+																						-			+															-				+		567
Normal perch				-		+																	-				-																	+	+						852
Walking	+				+																																												+		52
Head wave																																																			0
Squeak/chatter									+																																										15
PTC with sq/ch				+																																															8
Sq/ch with head wave tail fan																																																			0
Sq/ch with head bob																																																			0
Bill face																																																			1
Bill face with gape and squeak			+																																																13
Scratching																		+																																	11
Shaking																																																			8
Stretching																																																			4
Autopreen					+																																														60
Chewing																	+																																		20
Offering																					+																														5
Allopreen																			+		+																														45
Be allopreened																				+																															18
Move to				-				+												+			+		+							+													-						120
Move away																		+				+			+											+															49
PTC with head wave tail fan																																																			1
Regurgitation bobs			-	-	-																					+	+																								116
Bill touch																											+																								13
Feed another				-	+																		+		+	+																									118
Walk with head bob																																																			1
Walk with head wave tail fan																							+														+														7
Squeak Display 1				-																														+	+											+					59
SD 1 with head bob tail fan																																																			3
Squeak Display 2																																		+			+				+	+									31
Squeak Display 3																																																			3
Ah-Ah 1				-																									+	+		+			+							+									93
Ah-Ah 2																							+											+																	9
Ah-Ah 3																							+																												4
Copulation																							+																												8
Head bob																										+																									9
Bowing																																																			1
Tail fan																																																			1
Head bob with tail fan																																+		+																	13
Wing/head/tail																														+																					6
WHT with squeak																																																			0
Call			+	-																																															173
Half-call				-	+																				-		-																								352
Chuck																																																			5
Chuckle																																																			5
Walk with twist																																																			0
Into hollow																																																		+	27
Leave hollow			+			+																																													37
Column total observations	3	4	568	567	840	51	0	15	8	0	0	1	13	11	8	4	60	33	5	45	17	109	40	1	127	13	110	1	7	61	2	33	3	91	9	4	8	9	1	1	12	6	0	179	353	5	5	0	27	27	2497

Summary of sequential contiguity table for aviary males. The table was constructed from 100 hours observations of 9 males. The + indicate significant positive correlation, and − indicate significant negative correlation.

Preceding action / Following action	Drinking	Feeding	Pre-flight crouch	Flying	Normal perch	Walking	Head wave	Squeak/chatter	PFC with sq/ch	Sq/ch with head wave tail fan	Sq/ch with head bob	Bill face	Bill face with gape and squawk	Scratching	Shaking	Stretching	Autopreen	Chewing	Offering	Allopreen	Be allopreened	Move to	Move away	PFC with head wave tail fan	Regurgitation bobs	Bill touch	Feed another	Walk with head bob	Walk with head wave tail fan	Squeak Display 1	SD 1 with head bob tail fan	Squeak Display 2	Squeak Display 3	Ah-Ah 1	Ah-Ah 2	Ah-Ah 3	Copulation	Head bob	Bowing	Tail fan	Head bob with tail fan	Wing/head/tail	WHT with squeak	Call	Half-call	Chuck	Chuckle	Walk with twist	Into hollow	Leave hollow	Row total observations
Drinking			+			+																																													11
Feeding			+	−		+																																													37
Pre-flight crouch		−		+	+	−		−	−					−	−	−		−				−	−		−	−	−			−		−	−	−	−			+						−	−	−		−			1704
Flying		+	+		+			+	+					−						−					−	−	−					−	−	−	−			−						−	−	−					1683
Normal perch			+	−										+	+	+	+																											+	+						512
Walking	+	+		−				+		+					+			+																																	331
Head wave					+	+												+																											+						33
Squeak/chatter			+	−																																															148
PFC with sq/ch			+	−	+																																														61
Sq/ch with head wave tail fan						+																																													13
Sq/ch with head bob								+																																											4
Bill face			+																																																16
Bill face with gape and squawk																																																			11
Scratching			−	−		+									+		+	+																														+			81
Shaking			−	−	+									+		+	+	+																				+							+						161
Stretching				−											+																														+						43
Autopreen			−	−	+									+	+	+				+	+																							+	+						145
Chewing				−		+								+	+		+																											+				+			263
Offering																					+		+																												19
Allopreen						+															+																														34
Be allopreened																	+			+																															27
Move to				−				+	+			+							+							+																									73
Move away					+													+							+																										33
PFC with head wave tail fan																									+							+	+																		37
Regurgitation bobs																								+		+	+	+				+	+												+						196
Bill touch																									+																										33
Feed another																									+																										36
Walk with head bob																									+							+																			23
Walk with head wave tail fan																																+																			8
Squeak Display 1				−																									+			+						+								+					171
SD 1 with head bob tail fan																																		+																	31
Squeak Display 2			−	−																			+		+					+			+	+				+				+				+					179
Squeak Display 3			−	−																					+							+		+																	73
Ah-Ah 1			−	−																				+											+	+															34
Ah-Ah 2			−	−																														+																	99
Ah-Ah 3																																		+																	31
Copulation																																																			0
Head bob				−											+																	+													+						89
Bowing																																+																			17
Tail fan																																																			3
Head bob with tail fan																																	+																		9
Wing/head/tail																																												+				+			31
WHT with squeak						+																																													3
Call				−	+		+										+																									+			+	+		+			308
Half-call			−	−	+										+															+			+					+						+							159
Chuck														+																+														+							35
Chuckle																																																			13
Walk with twist				−										+																														+							81
Into hollow																																																			0
Leave hollow																																																			0
Column total observations	14	57	1719	1671	513	330	33	149	67	13	4	18	1	83	163	43	143	264	17	34	22	72	30	38	187	30	36	22	8	167	31	180	73	110	98	31	0	88	17	4	13	31	2	309	160	36	13	81	0	0	7186

difference is due to the fact that the tables were constructed from a number of different observation periods and a male may have been performing one action when observations began and another possibly different action when observations ceased. The grand total of both column and row totals is the same.

9.6.2 (ii) Results. The summary for field males is shown in Table 54 and was constructed from observations around nest hollows totalling 93 hours on 11 males and a total of 3497 following actions were recorded. The summary for aviary males is in Table 55 and involved 100 hours observation on 9 males. A total of 7186 following actions were recorded, over twice as many as field males.

In each table there were 2450 cells, each representing a possible following action. Only 292 (11.9% of cells) were entered in the field table and of these, 138 (5.6%) had frequencies of three or greater. Sixty-six (2.7%) of following actions had positive correlations and 29 (1.2%) had negative correlations. In the aviary table 661 (27%) cells were entered and 326 (13.3%) had frequencies of three or greater. One hundred and thirty-eight (5.6%) had positive correlations and 71 (2.9%) had negative correlations.

The tables have been arranged so that the positive correlations lie as close to the diagonal (upper left → lower right) as possible. This arrangement grouped behavioural units to a certain extent and showed those behaviours that formed transitions from one group to another, e.g. normal perch position.

The first major grouping concerns drinking, feeding, locomotion, normal perch and head wave. The field males were all observed in the area of their nest hollows and food and water were not always available nearby. As a result there were few data on these activities but both field and aviary males showed the tendency for drinking to follow walking, i.e. the birds settling away from the water source and walking in. The pre-flight crouch was always adopted before flying but it was followed by other activities although there were strong negative correlations with these activities. This indicated that a bird adopting the pre-flight crouch had a very strong intention to fly and usually did so.

The second grouping contained those displays associated with agonism. This grouping did not form a cluster as most of the other groupings did. Diagrams (flow diagrams) for these displays illustrating those which were positively correlated with them are shown for both field and aviary males in Figure 73. The field males showed little agonism and only 37 (1.1% of total following actions) were so connected. Squeak/chatter was followed by squeak/chatter with pre-flight crouch indicating a strong tendency to fly at or after the other bird or birds. Aviary males showed a wider range of agonistic displays and 253 (3.5%) were connected with agonism. The diagram for agonistic displays in aviary males on Figure 73 illustrates that these displays are positively correlated with locomotion. Squeak/chatter, the most common agonistic display, follows walking and flying by which methods a bird approaches another. Squeak/chatter was often followed by pre-flight crouch - the prelude

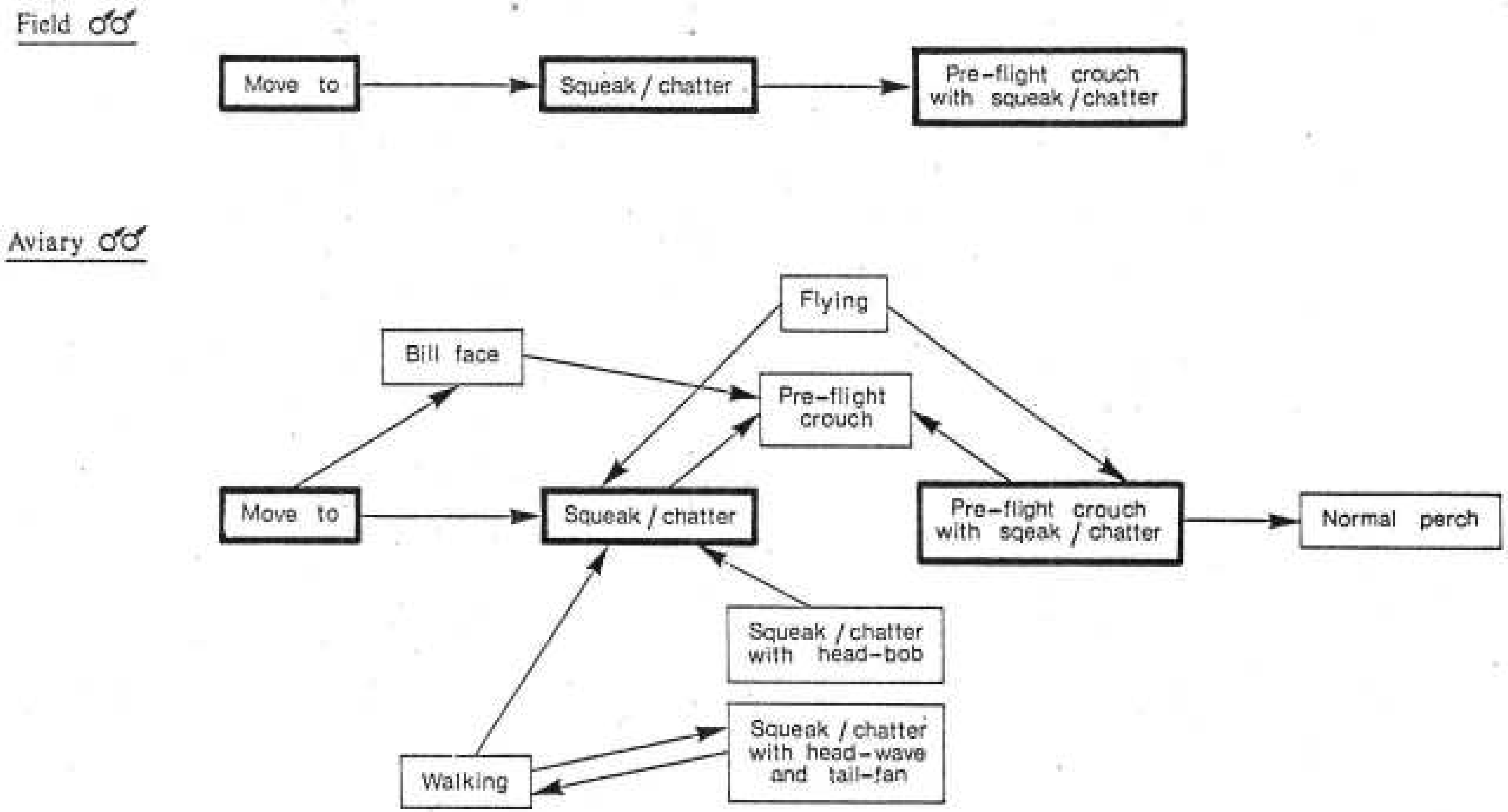


Figure 73. Flow diagram for agonistic displays. Arrows indicate direction of significant positive correlations. Those correlations based on cells with frequencies of less than 10 have been excluded.

to flying, either away because it had lost the encounter or in pursuit because it had won.

Comfort and maintenance displays (excluding feeding and drinking) formed the next grouping on Tables 54 and 55 and diagrams showing the correlations between these displays are shown on Figure 74. Field males performed these behaviours 103 times (2.9%) compared with 695 (9.7%) for aviary males. In aviary males there were positive correlations with the grouping of displays associated with allopreening and for this reason these displays are also included in Figure 74.

In field males chewing often followed scratching and was often followed by autopreening. It also often followed a definite move away from another bird. In aviary males the pattern was similar, but with more data available more correlations showed up. Scratching, shaking, stretching, chewing and autopreening show positive interrelations between each other and also with the normal perch position.

In field males allopreening and being allopreened were often performed in close juxtaposition and allopreening often followed a definite move to another bird. Offering, allopreening and being allopreened were 1.9% of total displays whereas in aviary males they were only 0.1% of the total. In aviary males both allopreening and being allopreened often followed autopreening and occurred in bouts of maintenance activities.

Regurgitation bobbing is a very distinctive series of actions and was so named because it appeared to be connected with forcing food up from the crop into the bill. Those displays that appeared

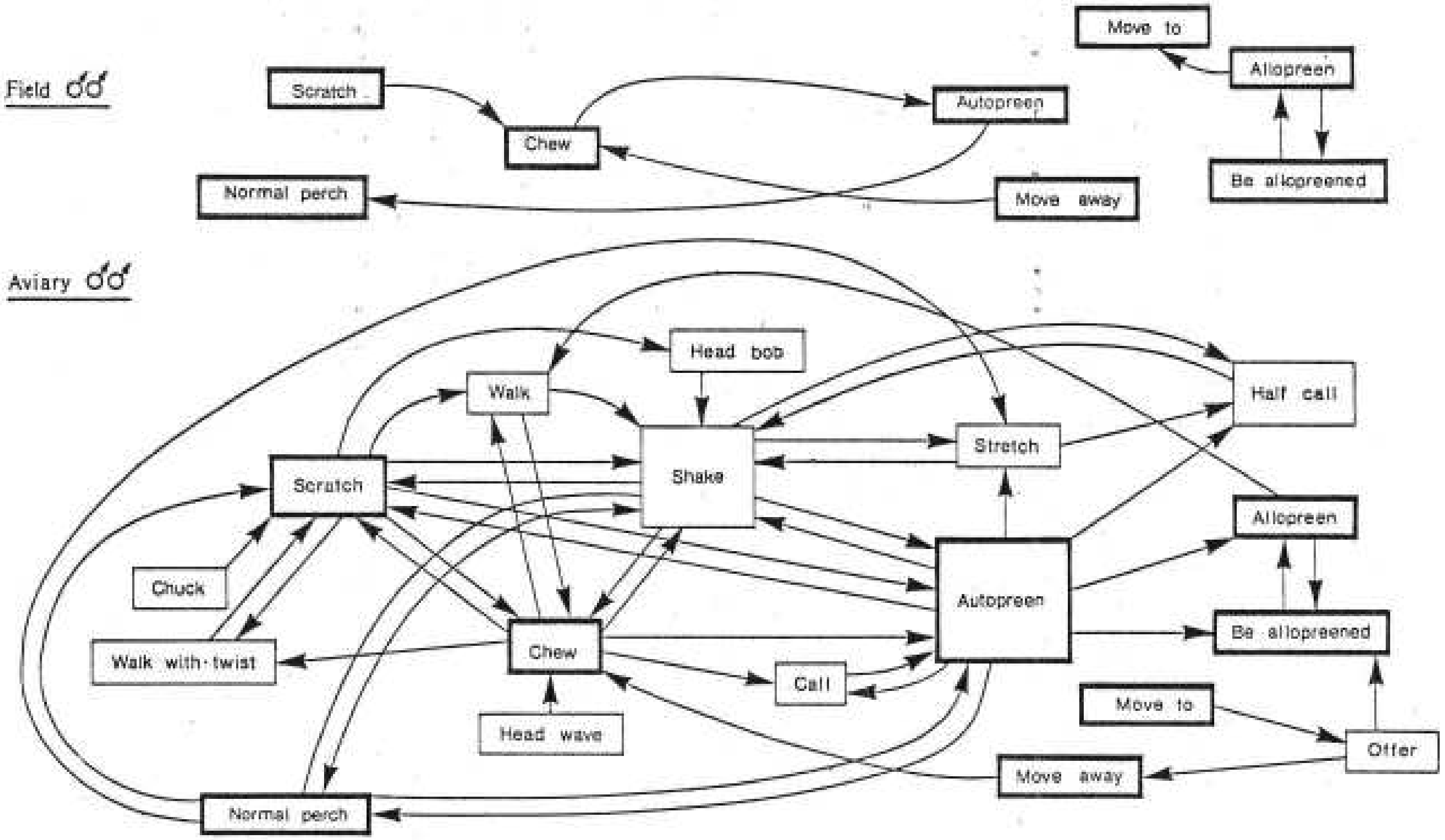


Figure 74. Flow diagram for maintenance and comfort displays.

to be correlated with regurgitation bobbing form the next grouping on Tables 54 and 55 and those that have positive correlations with this group are shown in Figure 75 for both field and aviary males. In field males regurgitation bobbing was followed by feeding another bird (always its mate) and this in turn was often followed by more bobbing. Bill touching was also connected with bobbing and food being transferred. It seemed to take place when one of the partners was not prepared for food to be transferred. They would touch bills briefly, withdraw them, lean forward and food transfer would take place. The pattern for aviary males was similar to the field males but there were far fewer instances of actual feeding (36 as compared with 118 in field males). In the aviaries regurgitation bobbing was positively correlated with Squeak Displays 2 and 3, pre-flight crouch with head wave and tail fan and walking with head bobbing.

The Squeak Displays and Ah-Ah Displays are displays made by males towards females and as such they have been grouped in the category of sexual displays. Field males performed 237 (6.8%) displays in this category while aviary males performed 918 (12.8%). The positive correlations between these displays and others are shown for both populations in Figure 76. In field males Squeak Display 1 and Ah-Ah 1 were the most frequently performed. Squeak Display 1 was often followed by Ah-Ah 1 and vice versa as was Squeak Display 2. Copulation was recorded eight times during these observation periods and Squeak Display 2 was the only display correlated with it. In aviary males Squeak Display 1 and 2 and Ah-Ah 1 were the most commonly performed displays in this category with Squeak Display 1 correlated with Squeak Display 2 and Squeak Display 2 with Squeak

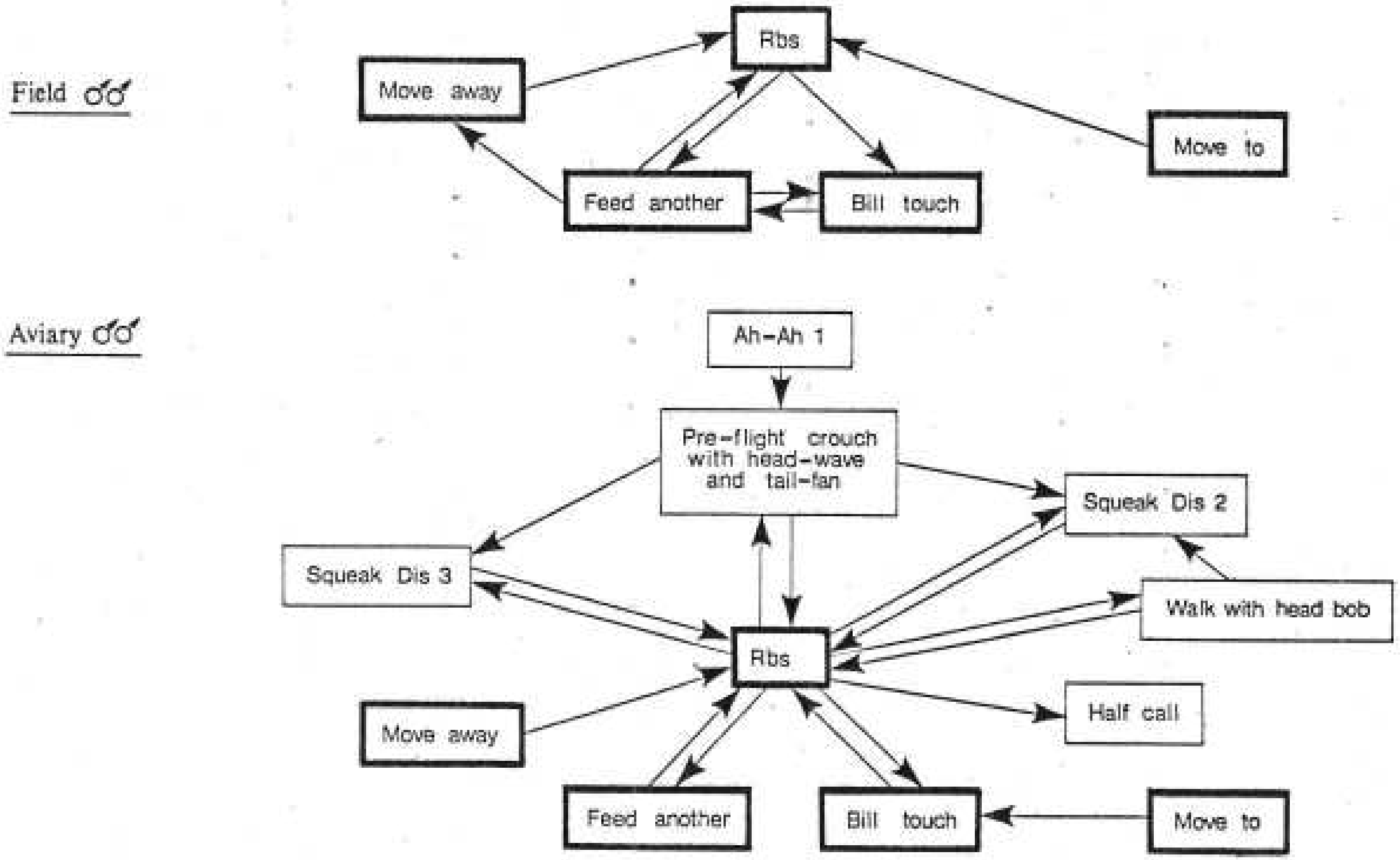


Figure 75. Flow diagram for displays associated with courtship feeding.

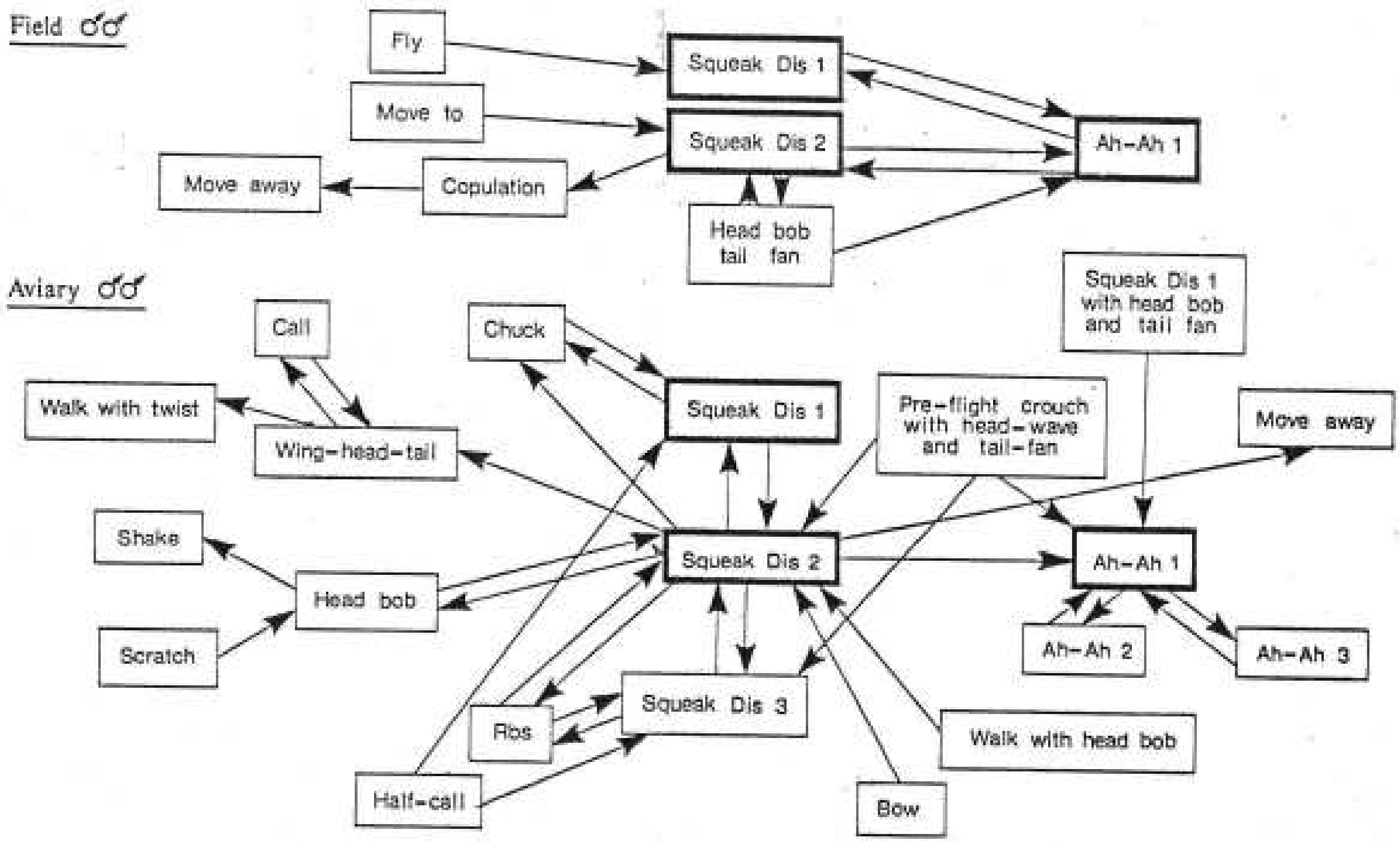


Figure 76. Flow diagram for sexual displays (excluding courtship feeding). Copulation has been included although the frequency was less than 10.

Display 3. This pattern is different from that shown by field males and regurgitation bobbing was correlated with both Squeak Display 2 and 3. The incidence of many displays was low and apart from their positive correlations with the Squeak Displays or the Ah-Ah Displays, nothing could be determined about their possible function. No copulations were seen in the aviary population at any time during the study.

The last major grouping in Tables 54 and 55 concerns the audible vocalizations made by males. The displays that were positively correlated with these vocalizations are shown on Figure 77 for both populations. In the field, males showed a tendency to call (Wy-lah call) prior to adopting the pre-flight crouch and to give the half-call from the normal perch position without showing any tendency to fly. The half-call was particularly common when a male was sitting in the vicinity of its nest hollow while his mate was out of sight in the hollow. In the aviary both call and half-call were positively correlated with each other and the call was also correlated with walk with twist and normal perch position. Half-call was also correlated with the normal perch position and there was a tendency to perform Squeak Displays 1 and 2 after giving the half-call as well as shaking and head bobbing.

Walk with twist was only seen in aviary situations and was never seen in the field. Males in aviaries were never seen entering or leaving hollows unlike males in the field.

9.6.2 (iii) Discussion. The sequential contiguity tables for both field and aviary populations were constructed from

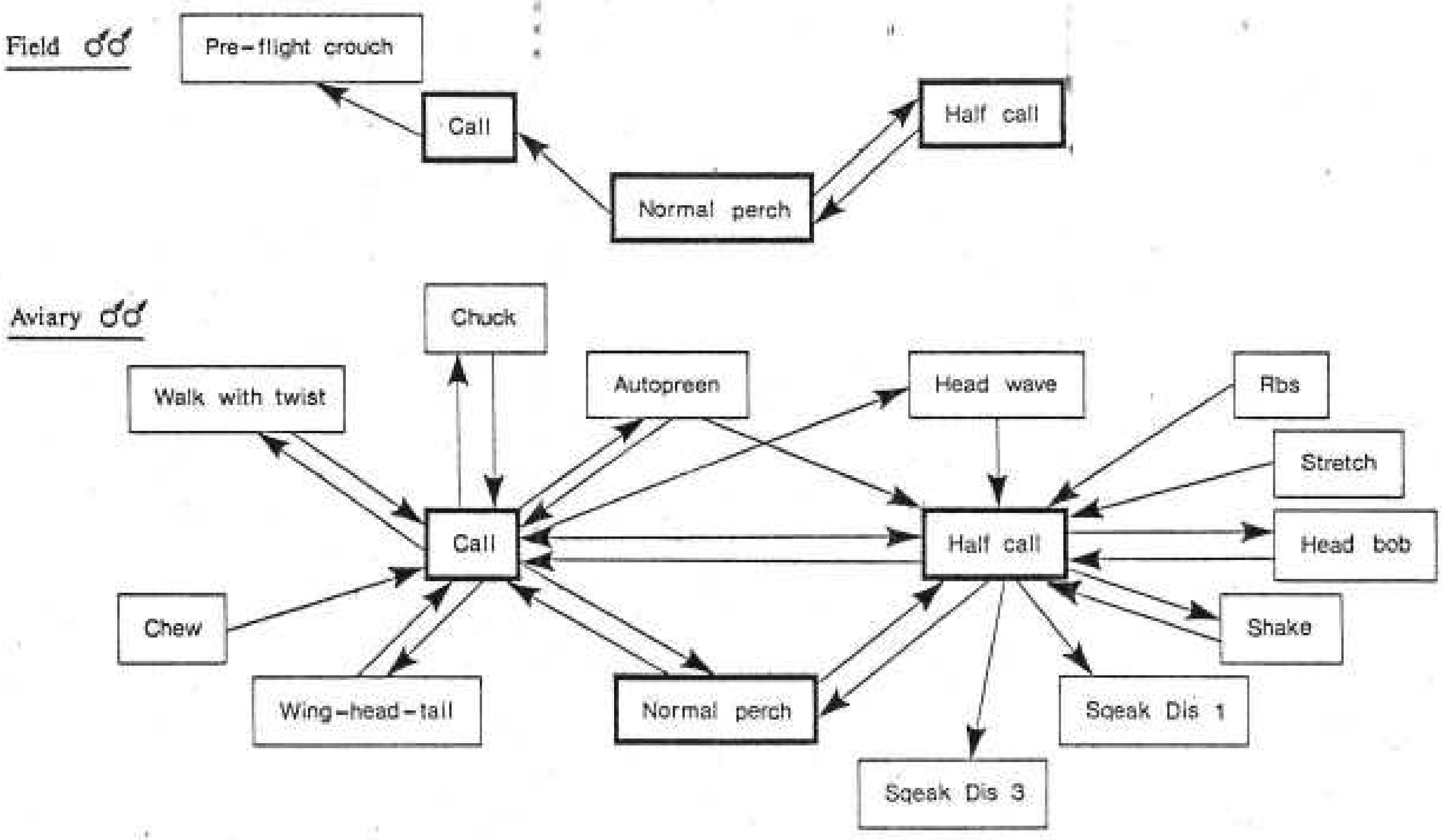


Figure 77. Flow diagrams for displays associated with Wy-lah call and half-call.

observations on a number of different individuals in a variety of different circumstances. No effort was made to control the external conditions under which the observations were made. As a result the patterns of behaviour may have been modified by a wide range of environmental influences, both endogenous and exogenous. Despite environmental and individual differences it should be possible by observing a number of different individuals to group displays into categories. In addition, by comparing populations of males from field and aviary it should be possible to investigate broad differences in behaviour between the two populations.

The first obvious difference between the two populations shows up in the fact that in the field males appeared to sit inactive more than in aviaries (normal perch 24% of total compared with 12%). In the field males were observed for this quantitative phase of the work in the area of their nest hollows. This was because the breeding behaviour was the main interest of the study of behaviour and this area was one where the observer would guarantee unrestricted observation. In the aviaries, in contrast, the birds were observed at different times of the year and mainly at a time of day when the birds were more active - early in the morning and so, many more following actions were recorded and the males spent less time sitting in the normal perch position.

By placing birds in aviaries a set of space limitations are placed on them. In the wild the birds are not restricted to any single location and food and water were usually not available in close proximity to nesting site. By necessity, in aviaries these requirements must all be located in one very restricted site. The effect of these restrictions shows in agonistic encounters. In the field the loser of such an encounter usually moved sufficiently far away to be involved no longer. In the aviary the loser sometimes could not get sufficiently far away and so the encounters were continued when they may have been terminated had the bird been able to escape. As a result, agonistic behaviour formed a higher percentage of the total in aviary males (3.5% compared with 1.1%).

Comfort and maintenance displays were also much more commonly displayed by males in aviaries (9.7% compared with 2.9%) and of these, chewing was particularly interesting. The fact that it has strong connections with other maintenance functions leads to the conclusion that chewing has a maintenance function and serves to maintain the mandibles by continually wearing them down, as suggested by Dilger (1960). In the field, chewing was only 0.01% of the total activities recorded, yet in the aviary males it was 3.7%. The diet of the two populations differed markedly, aviary males being fed sunflower seed with soft husks while in the field the birds ate seed which had to be extracted from hard seed pods. It is possible that the lack of hard fruits means that aviary birds must chew at objects other than food more frequently than would be required in the field.

Allopreening was only seen performed between mated pairs in the field (and, once breeding had finished, between adults and their offspring). The increased incidence of allopreening in the field may indicate some purpose in maintaining contact between paired birds.

During the period that the female was incubating and brooding the contact between the male and female was brief - in some cases only 10 minutes a day. The contact between the pair during allopreening may be a very important method of reinforcing the pair bond during this period. There was no evidence in either field or aviary observations that allopreening had an agonistic function as suggested by Goodwin (1956, 1959 and 1960) and discussed at length by Harrison (1965). The offering position adopted by one bird in relation to another often resulted in the bird being allopreened but it was not always successful. On some occasions, if the bird in the offering position was not allopreened it would butt the other bird in the side or chest with its head then resume the offering position. The argument put forward by Harrison (loc. cit.) was that the bird being allopreened was the less dominant individual yet allopreening took place between both members of the pair regularly. In the field, around the nest hollows, males allopreened females over twice as much as they were allopreened by the females (45 incidents to 18) and experiments (section 9.8.3) and observations showed that the female was the dominant individual in the pair.

In the field, over the period these observations were made, the males were responsible for providing food for the females. In the aviaries, in the few breeding attempts that did take place, the females foraged for themselves (food being abundant near the hollow) and the males did not have this obligation. In view of this it was not surprising that male feeding female incidents were so low compared with the field (36 compared with 118). In both field and aviary, males did feed females during the non-breeding season and this process may also be important in reinforcing the pair bond throughout the year.

The fact that courtship feeding does take place throughout the year and that regurgitation bobbing is correlated with the Squeak Displays (Figure 76) adds support to this theory.

Move with twist, although seen only in aviaries, was not performed by all aviary birds. Two which had been in the aviaries all their lives were never seen performing it and some individuals performed it more than others. The strong correlation between move with twist and calling indicates that it might be associated with a thwarted intention to fly. There was a noticeable increase in its performance during periods when wild birds were flying down the valley, calling loudly within range of the aviary population. This usually resulted in periods of calling associated with move with twist. Overcast and rainy weather seemed to unsettle the birds and calling and move with twist were noticeable during these periods.

The results of these analyses show some major differences in behaviour between males in field and aviary populations, particularly in the incidence of certain displays. Any interpretation of the function of some of these displays (particularly those regarded as sexual) based on these analyses is difficult because of the different constraints on the two populations (one a free flying population consisting of breeding pairs with a strong pair bond; the other a caged population consisting of individuals the strength of whose pair bonds were not known).

These analyses did show that the displays could be grouped into categories which could be used in the interpretation of results obtained from studying the behaviour of the birds in the field.

9.7 Behaviour of birds in the field population. White-tailed Black Cockatoos do not breed until they are at least four years old (section 5.7.2) and for the first year the immature birds are dependent on their parents. Little is known about their associations with other birds between their second and fourth years.

Once the birds take a mate they do so for the life of one of the partners. With only one exception during the study, when a bird took another mate its previous mate was never seen again (from observations of 22 males and 20 females known to have taken another mate). The pair involved in this one exception were marked in 1973 during which they successfully fledged a nestling. In 1974 they nested unsuccessfully, failing for some reason when their three week old nestling died early in October. They were next seen on 24th January, 1975 in a group of about 300 birds along the Hill River. The female (SZ) was sitting with an untagged male and the male (MM) was sitting with another female (LI) in a nearby tree. From the way the two duos were acting it was obvious that they were paired and in the following breeding season SZ and an untagged male successfully fledged one young while LI and MM were seen together several times during the breeding season.

9.7.1 Daily routine and behaviour during the non-breeding season. During the non-breeding season the birds remain in foraging groups made up of pairs with their fledglings, pairs who have bred but failed or have lost their fledglings and immature birds (one year or older). During this period the daily activity pattern was constant. After dawn the birds moved away from the area of the roost to the feeding area and remained there until about 1000. They then moved gradually back to a water source, drank and then moved to trees nearby and settled. During very hot weather this took place early in the day before it got hot, but in the cooler weather this took place at 1100-1200.

From 1500 (or even later in very hot weather) the birds moved out and began feeding. This continued until about an hour before dark when the birds returned to water and drank. Just prior to dark the birds moved off to roost. Once they had settled in the roost trees the birds remained quiet and stayed in the roost the following morning until there was light enough to see.

Males occasionally fed their mates during the non-breeding season, with or without the female begging prior to being fed. They also allopreened together, especially in the evening or in the middle of the day. Males occasionally performed the Ah-Ah Displays and the Squeak Displays (particularly Ah-Ah 1 and Squeak Display 1) during this period but there was no noticeable response from the females apart from an agonistic action if the males approached the females during the performance of the displays.

The young birds remain with the parents from the time they leave the nest hollow until just prior to the adults returning to breed. Immediately after fledging the young birds would beg constantly from the adults or continually utter the "grate" call. The presence of dependant young in a group of birds was indicated if this call was uttered. As the fledglings got older they begged less and fed themselves more, but when sitting near their parents at mid-morning or at dusk, they often begged from them. Both adults fed the fledgling and both allopreened it. Allopreening between parent and offspring differed from allopreening between mates as it was not restricted to the head and neck. These areas and most of the body surfaces of the fledgling may be allopreened by a parent, but the adults would not allow the fledgling to allopreen them, and they rejected it if it attempted to do so.

With the start of the breeding season the family groups break up, the adults returning to the breeding area and the young birds becoming completely independent and remaining with other immatures in foraging groups. This process of the break-up of the family unit was never seen and the method by which it was accomplished is not known. In six cases the immatures returned to the breeding areas with the adults and were obviously associated with them. TT was fledged by female MH and an untagged male from hollow 107 in December 1975. This family was seen along the Hill River the following January and in September 1976 they were seen together in the area of 107 only eight days before MH laid in that hollow. TT was not seen with MH subsequently. HP was fledged by female UG and an untagged male from hollow 132 in 1974. The following January and February this group was seen along the Hill River and in July 1975 this group was seen around the area of 132 several times, the last being 14 days before UG laid in 132. Here again, HP was not seen with UG after laying.

The fact that the immatures were still associated with the adults at this stage was shown by female MZ and male QI who fledged GN from hollow 90 in 1974. This family group was seen eight times between January and March along the Hill River then they were re-sighted in the breeding area in July close to the area of hollow 90. GN was begging loudly and male QI was making vigorous regurgitation bobs and moving towards GN when all three were chased off by another female. GN was subsequently seen (October) in the breeding area feeding in a group of birds and neither of its parents were present.

The final incident of association of adults and offspring in the breeding area the following breeding season concerned male ML who, with female SW, fledged TH from hollow 105 in Dec. 1975. They were seen together along the Hill River in January, then the next sighting was made in mid-September in the area of 105. ML had re-mated with an untagged female (SW was never sighted after the January sighting) and he was allopreening TH. TH was seen with ML until mid-November when it disappeared. ML's mate nested in the area of 105 but I did not find out which nest they were using.

There were only two instances of immature birds being seen with one or other of their parents over a year after they fledged. The first example concerned RR which was fledged by female LA and male SD early in December 1973. The following January and February this group was seen together along the Hill River, LA was not seen after this but SD remated with an untagged female later in 1974. RR was re-sighted twice in January 1975 in a group of about 300 birds along the Hill River. On these occasions it appeared to be alone then shortly after it was seen in association with SD and they were flying and sitting together throughout the four hours the group was observed. (RR was an immature male so SD was not mated to it and there was an untagged female with SD during this period). The other example involved female UY and male ZN who fledged XA from hollow 50 in December 1974. In September, 1975, UY was brooding a young nestling in hollow 50 and one evening ZN flew in accompanied by XA and settled near 50. XA was begging loudly from ZN. UY left the hollow and all three flew off together. XA was not seen for the remainder of the year but UY and ZN were seen on three different occasions. This pair successfully fledged a nestling but it was not seen subsequently. The pair were next seen in March 1976 along the Hill River together with XA which was being allopreened by UY.

Apart from these two instances, the association of the pair with their fledgling ceased either just prior to or just after the start of the next breeding season.

It was not possible to investigate the process of the break between adults and their offspring in the aviary situation. The only successful breeding attempt in the aviary that may have been used in such an experiment was upset when the nestling fledged. It flew into the side of the aviary and concussed itself, resulting in paralysis down one side for several weeks and it never completely recovered.

9.7.2 Behaviour during the breeding season. With the return of the pairs to the breeding area the remainder of the breeding season may be divided into three main phases: the selection and preparation of nest hollows; the laying and incubation of eggs; and the nestling period. The following sections deal with the behaviour of the birds in the vicinity of their nest sites (i.e. within visual distance of an observer watching the nest sites).

9.7.2 (i) Selection and preparation of nest hollows. With the start of the breeding season the birds move back to the breeding areas in small groups. While some pairs are in the area selecting and preparing hollows, others have not yet returned to the area. Once back in the area the pair commenced searching for a suitable hollow in which to nest. This searching was carried out around mid-morning by the female with the male accompanying her but taking no part in the investigations. Initially, the search involved the pair flying into an area and the female moving round the area from tree to tree examining different hollows. This it would do by looking into the hollow, walking round the entrance, chewing briefly at the entrance but not entering the hollow at this stage. The male would sit nearby and follow the female from tree to tree. The total time spent by females in the vinity of their future nest hollows during the preparation stage is shown for four females on Figure 78. Also shown in this figure is the time the females spent inside the hollows. The earliest any of these birds were seen in the area prior to egg-laying was 40 days. This difference between individual females is shown clearly in this figure. In both 1973 and 1974 MX started prospecting much earlier than the other birds and in both years, AN started much later, and was not seen in the area of its future nest until nine days or less before laying.

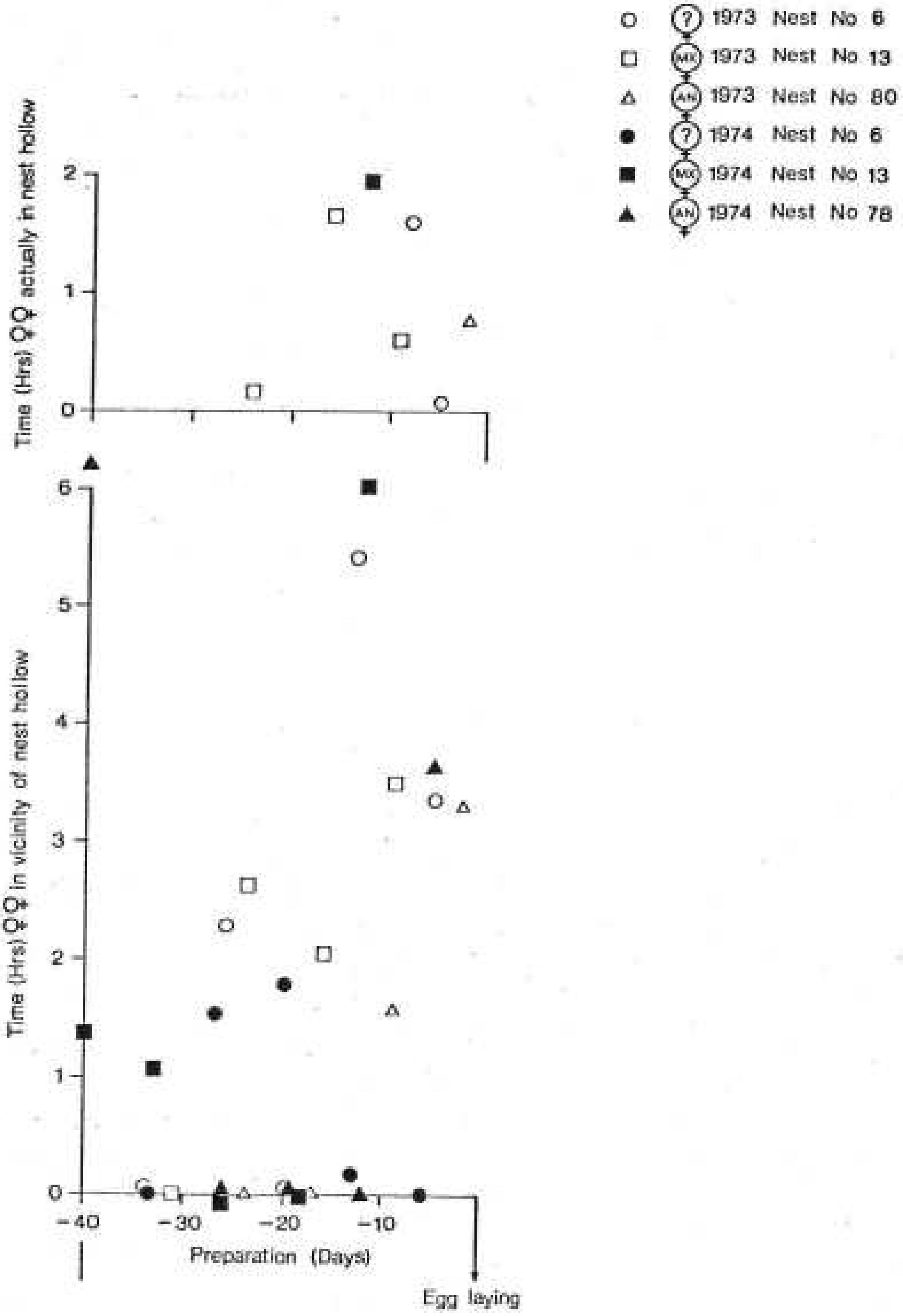


Figure 78. Preparation stage: Total time females in vicinity of future nest sites and total time females spent inside hollow. A zero record indicates that the female was not seen during that particular nest watch.

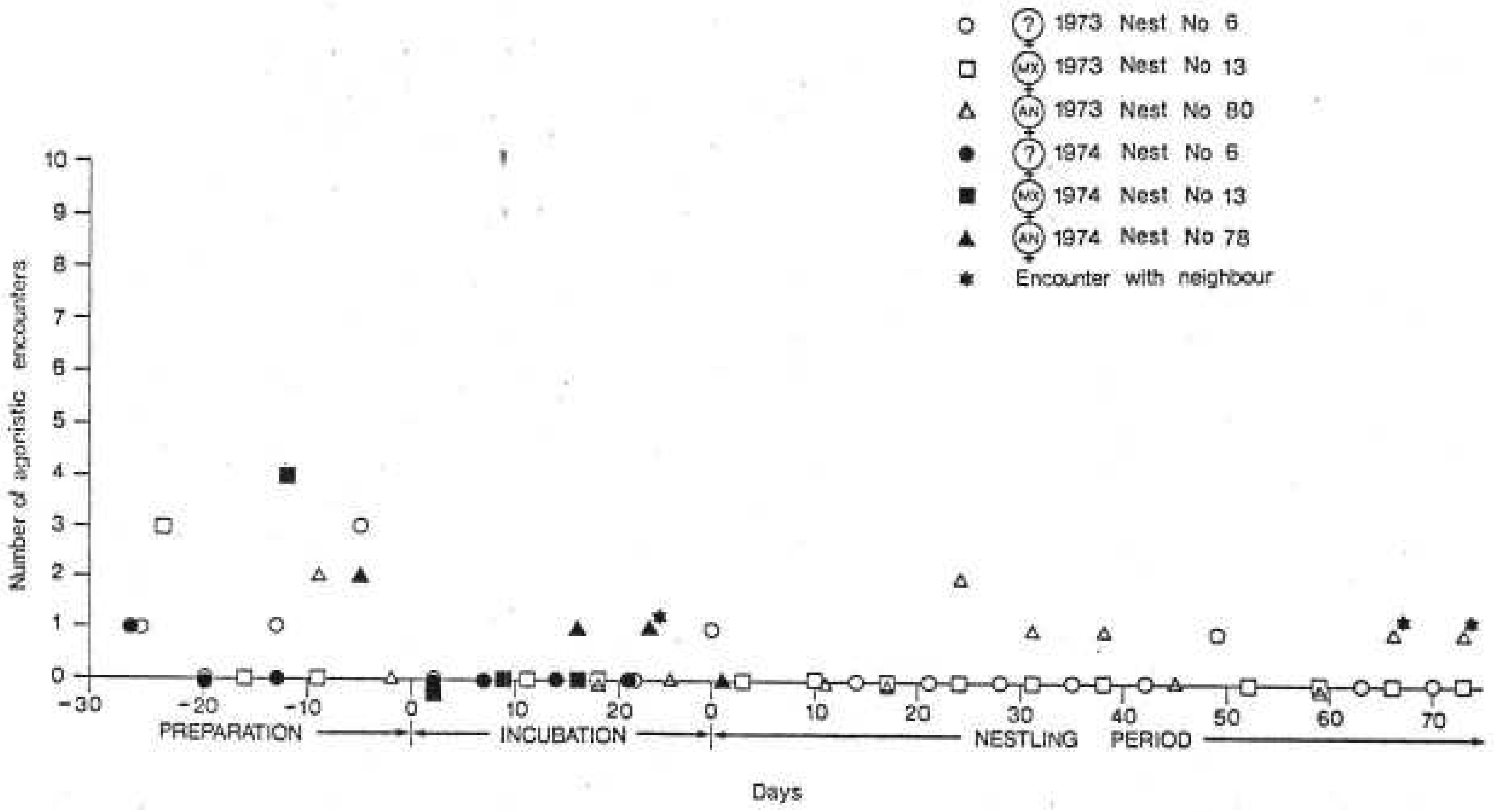
During the early visits the females did not spend long near any one hollow, but investigated a number of different hollows around the general area. In subsequent visits they spent more time around the hollow they later used but they occasionally went to look at other hollows nearby.

The time spent inside the hollow prior to egg-laying also varied between females (Figure 78). MX started entering hollow 13, 24 days before laying in 1973 and during each subsequent visit spent some time in the hollow. AN did not enter any hollow for any length of time in either year until two days before laying in 1973 and was not seen to enter any hollow entirely prior to laying in 1974. It did back into the entrance of a number of different hollows in the area. Those females that did spend some time in the hollow spent part of the time chewing at the inside of the hollow. The eggs are laid on a bed of wood chips and from those hollows that were close to the hide a steady sound of splitting wood could be heard from the hollows whenever the females were inside prior to laying.

Although most of this preparation activity took place around mid-morning some birds did occasionally visit the area in the evening but none of them roosted near their future nest hollows. The birds always joined a group in a roost which was in trees along a creek south of the observation area.

The number of agonistic encounters between females preparing their hollows and other females in the area is shown for four females on Figure 79. During the preparation stage there were more such encounters than in the following two stages. In addition, during

Figure 79. Number of agonistic encounters between breeding females and other conspecifics.



the preparation stage the females chased other females further from their nest hollows than they did in the rest of the breeding season. For example, 16 days before laying, AN chased a female from tree 78 (in which AN later nested). The female flew from 78 and landed in a tree nearby which also had a suitable hollow in it. AN squawked loudly and flew towards the female and chased it well beyond the tree, before circling and landing in 78. Once the females had laid they would tolerate other females in their nest tree, but not near their hollow entrance. If a female investigated an occupied hollow, the occupant would start squawking loudly and continue until the intruder withdrew. If an owner was outside the hollow when the intruder was inspecting the entrance then the owner would chase the intruder from the entrance, but not necessarily out of the tree.

During the entire study males were never seen initiating any agonistic encounters with females. Around the hollow males did chase intruding males away while their mates dealt with the females. Throughout the year males threatened any male that went too close to their mates but they did not pursue them once they had moved away from the female.

9.7.2 (ii) Incubation and nestling stages. The daily routine of the pairs during these stages has been discussed earlier (Figure 32) and from the time eggs were laid the females did not interfere with other birds in the area unless they went near their nest entrance. During these stages the females showed the same basic routine with little variation between individuals and the birds from neighbouring nests often left and returned in a group during their daily activities.

9.7.2 (iii) Male behaviour in the vicinity of the nest hollow. The total time spent by the males in the area of the nest hollow while their mates were in the hollow is shown on Figure 80. During the preparation stage the males remained in the area with the females and none of the males was ever seen entering or leaving a hollow. (No male was seen in a hollow until they started feeding the nestling after about 20 days after hatching.) Once the females laid the first egg they incubated continuously and this abrupt change in routine obviously affected the males. Prior to this the pair had flown into the area together and left together, despite the fact that the female may have spent some time out of sight in a hollow. The effect of this change on the males was shown by the amount of time they spent sitting near the hollow after the females had returned to incubate. Some males spent up to two hours waiting for the females to reappear before flying off alone. By seven to ten days after laying the males had adjusted to this change and spent very little time waiting around after the females had re-entered the hollow. This pattern continued until about ten days after hatching when the females started changing their routine. From this time they usually left with the males at dawn and returned mid-morning and spent the remainder of the day brooding. Once again it took some time for some of the males to adjust to this change. There was considerable variation between individuals in the time they spent waiting. For example, male 78 in 1972 did not wait around long once the female re-entered the hollow but male 6 in 1973 spent up to three hours waiting. During these periods of waiting the males sat immobile uttering the occasional half-call then starting

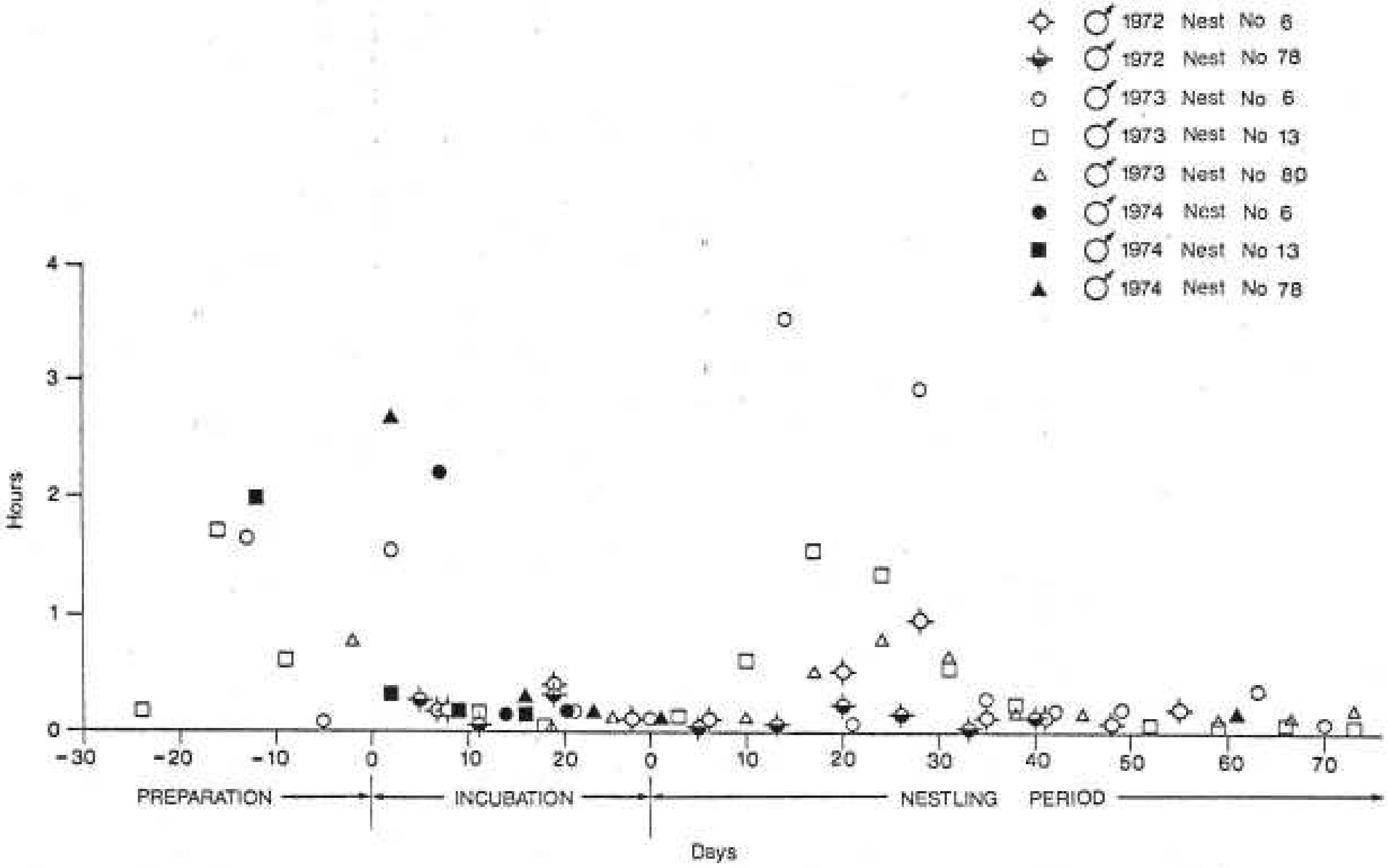


Figure 80. Total time males spent in vicinity of nest hollow while females were in hollow.

a series of calls before flying off alone calling loudly. By about 30 days after hatching the females had adjusted to the routine of spending all day with their mates and brooding the nestlings at night and the males spent little time waiting around after the females had entered the hollow for the night.

During the preparation stage males fed and allopreened their mates occasionally but during incubation and the first 10 days after hatching the males always fed the females at the visits at mid-morning and dusk but they did not allopreen with them on every visit. From 10 days after hatching, as the females spent longer out feeding with the males, the males fed the females less. If the males fed the nestlings directly they usually did not feed the females as well but if they did not feed the nestlings then they always fed the females. Allopreening occurred occasionally throughout this part of the nestling period.

Copulation was only seen in the vicinity of the nest tree and was seen at varying times from 26 days before laying until six days after and was not seen on every visit by the pair. The occasions when copulation was observed during the hide observations are shown on Figure 81.

The most common displays performed by the males towards the females (apart from allopreening or feeding) in the vicinity of the hollows were the Ah-Ah and Squeak Displays. Of these displays Ah-Ah 1 and Squeak Display 1 were performed more frequently than the others (93 Ah-Ah 1 compared with 13 Ah-Ah 2 and 3 combined; 59 Squeak Display 1 compared with 33 Squeak Display 2 and 3). The number of Ah-Ah 1 and

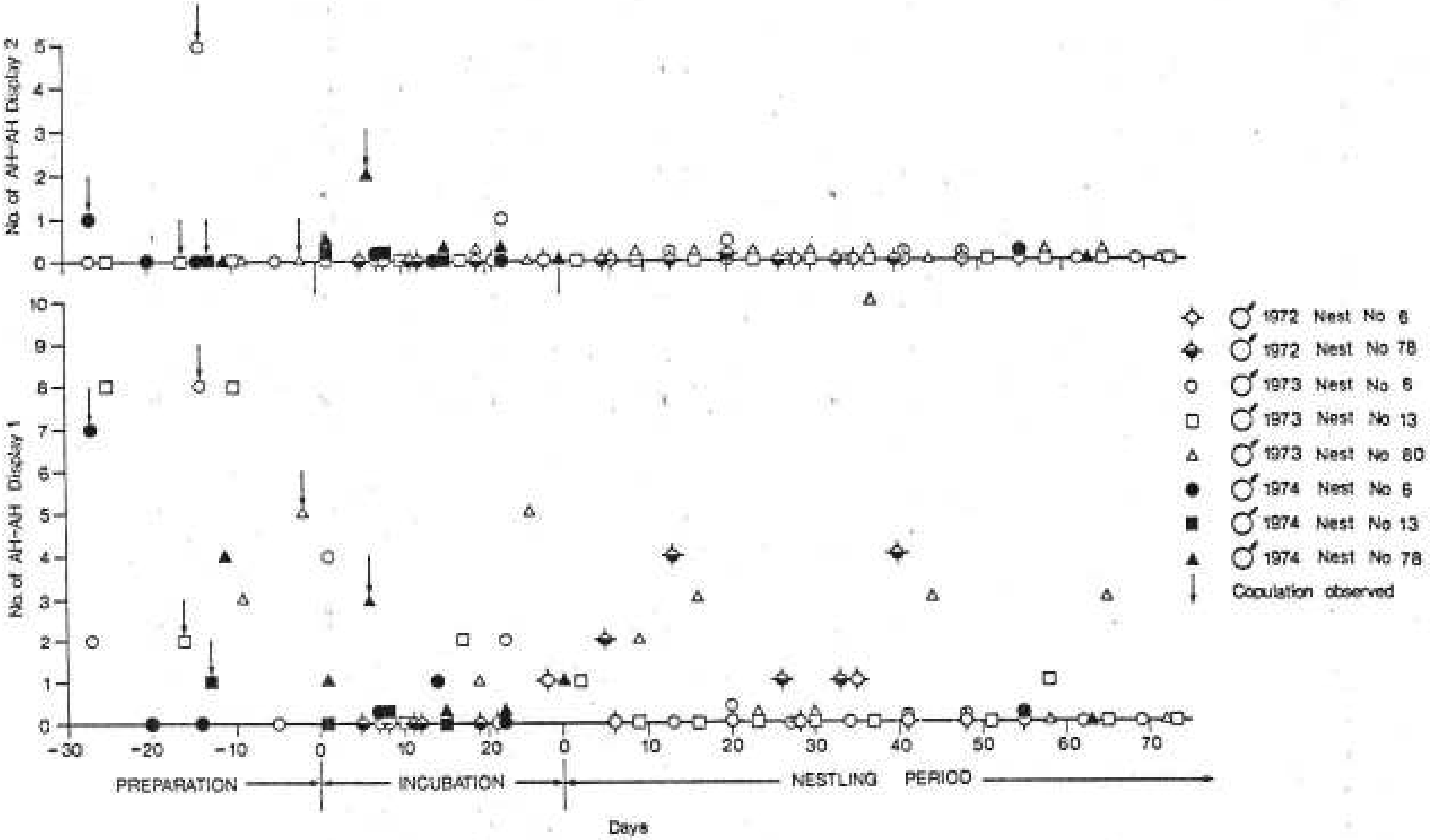


Figure 81. Number of Ah-Ah Display 1 and 2 performed by individual males in the area of the nest hollow.

Ah-Ah 2 performed by individual males throughout the breeding season in the area of the nest hollows is shown on Figure 81. There were too few Ah-Ah 2 performed to discuss but the pattern of performance of Ah-Ah 1 was highly variable. Male 6 in 1973 performed Ah-Ah 1 in the preparation and incubation stages but was not seen to perform it during the nestling period. Male 13 in 1973 followed a similar pattern. Male 80 in the same year performed Ah-Ah 1 consistently throughout the breeding season.

Treating the data on Figure 81 differently shows that there is a trend of decreasing performance of Ah-Ah 1 through the breeding season. By taking all the points on the Figure into consideration, of the 13 observations made during the preparation stage, 10 (77%) of them had one or more Ah-Ah 1 performed during the period around the nest hollow. During incubation this falls to 10 out of 25 (40%) and during the nestling period to 13 out of 42 (31%).

The number of Squeak Display 1 and 2 performed by individual males is shown on Figure 82. The data for Squeak Display 2 are limited but they show the same trend as the Ah-Ah 1 displays with decreasing performance through the breeding season. During preparation, seven out of 13 (54%) compared with four out of 25 (16%) for incubation and four out of 42 (10%) for the nestling period.

The same trend applies with Squeak Display 1 with relatively more being performed during the preparation stage. During preparation 10 out of 13 (77%) compared with five out of 25 (20%) during incubation and 10 out of 42 (24%) during the nestling period.

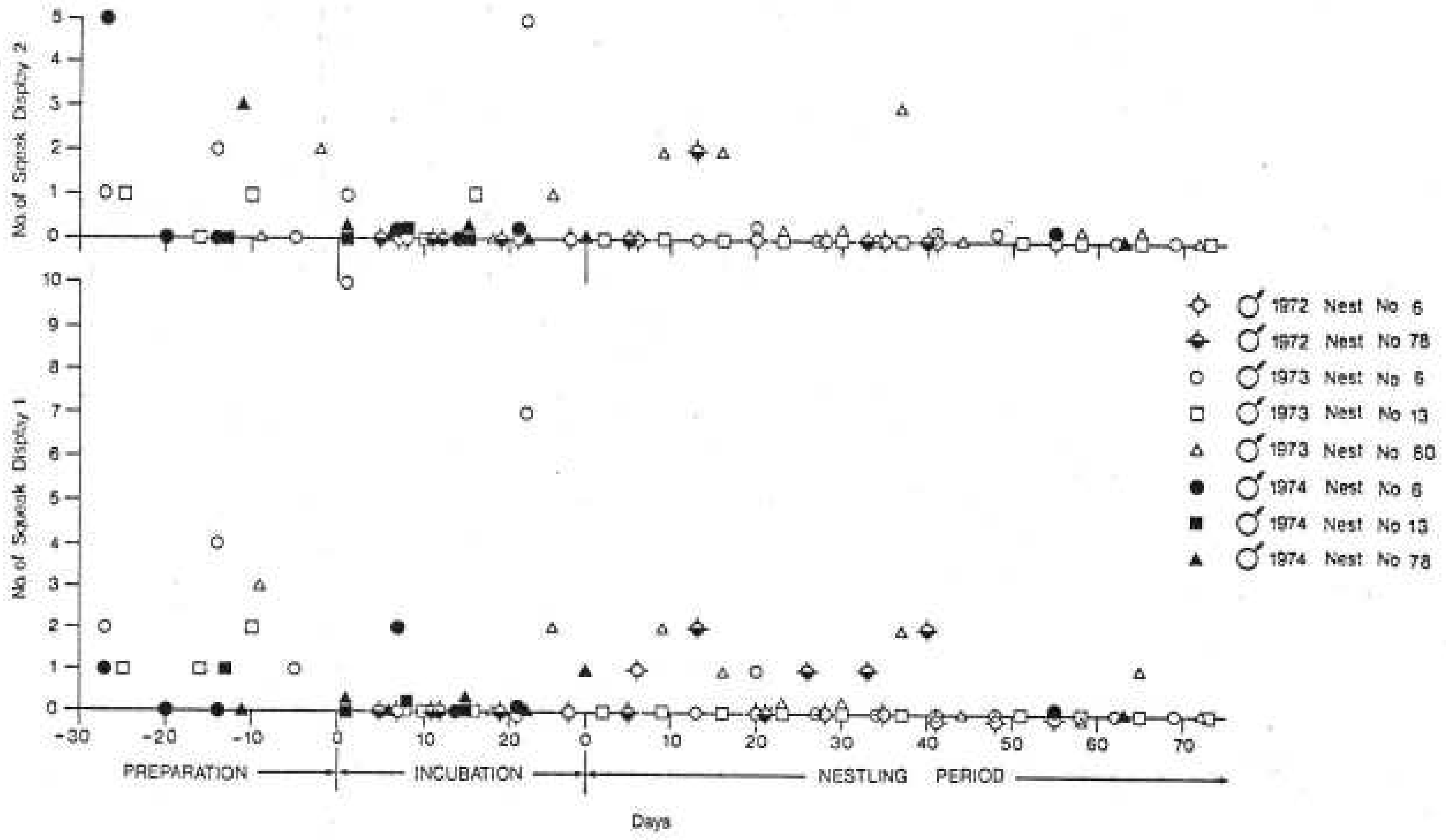


Figure 82. Number of Squeak Display 1 and 2 performed by individual males in area of nest hollows.

9.7.2 (iv). Parent/young interactions. There appeared to be a strong bond between adults and their nestling and as long as it was alive and in the hollow they would continue to feed it. In 1973 one nestling had damaged its wing when it was about 50 days old. As a result the wing was malformed and useless. This nestling remained in the hollow for 140-150 days (twice the normal nestling period) after which it disappeared. During this period the adults (female EF and male QN) continued to feed it and its weight at 140 days was the same as its weight at 80 days. During the last six weeks of this period this pair were the only birds left in the breeding area. The other birds had left and were in the non-breeding season groups. EF and QN were flying out to join these groups during the day and returning to feed the nestling in the evening. The closest point these groups were foraging to the breeding area was 17 kilometres.

In the event of the death of the female, the male will continue to look after the nestling in certain cases and this varied with individuals. In 1974 the female at 106 disappeared when her nestling was around 30 days old. The male continued to look after the nestling which fledged at the average age and weight. On the other hand in 1975 UG was taken by a Wedge-tailed Eagle when her nestling was about 25 days old. The male spent long periods in the nest tree, near the hollow, calling loudly. It did not go into the hollow and feed the nestling despite its very loud insistent begging whenever the male was around and the nestling died. In another example, female MO was taken by a Wedge-tailed Eagle when her nestling was about 60 days old. The male maintained the nestling which fledged at 73-80 days and was above average weight; this fledgling was seen three years later in a large non-breeding season group. There were no known cases where the male disappeared leaving the female alone.

There were considerable differences in the behaviour of nestlings at the time they fledged. Some sat waiting in the entrances until their parents returned. As soon as the adults appeared the nestlings jumped clear of the hollow and started flying. The adults joined them in the air and flew off calling loudly with the fledgling flying with them. Other nestlings spent several days, when their parents were around, sitting in the entrance adopting the pre-flight crouch, continuously appearing to take off but not doing so. In one of these cases one evening, the male flew down to a point near the hollow and started regurgitation bobbing. He and the nestling leant towards each other in order to transfer food. The male withdrew slightly before the bills touched and the nestling leant further out of the hollow towards the male. It overbalanced, fell out of the hollow and started flapping its wings. The adults took off and flew off with it in the direction of the roosting point.

9.8 Aviary studies. Observations made in the field raised certain questions which it was not possible to answer from data derived from field studies. In order to provide answers to some of these questions certain experiments were conducted on the aviary population. These experiments are set out below.

9.8.1 Feeding. Apart from the period when the female was incubating or brooding, the members of the pair were together throughout the year. The birds usually sat or flew close to their mate. Field observations indicated that when the birds were feeding the members of the pair were sometimes separated - one feeding, the other in a nearby tree or perch. In order to see if the presence of one member of a pair feeding attracted the other member to feed, an experiment was carried out in the T-aviary. This involved six pairs of birds which had been placed in the aviary as a group a month before the experiment began. Food (sunflower seed) was broadcast over an area of sufficient size to enable the birds to feed without being bunched up (as around a feed tray). During observations, on each occasion that one of the birds went to feed the presence or absence of its mate in the feeding area was noted. A total of 154 feeding bouts were observed and the results are shown on Table 56. The data were analysed using the Spearman Rank Correlation Coefficient Test (Siegel, 1956) and confirmed that an individual's feeding was not related to its mate's activities in the feeding area.

9.8.2 Pair formation. The pair appeared to be the basic unit of the social system but the process by which two individuals form a pair was not seen in the field. In order to investigate this process an experiment was conducted in the Small Aviary. Five adult males and seven adult females were involved in the experiment and all were caught as adult breeding birds. Male A and female A had been caught together and were a known pair. (They were the only pair to breed successfully in captivity during the course of the study.) The remainder of the birds had been grouped in the T-aviary for several months and were divided into pairs on the basis of which male and female were observed allopreening together. On establishing which birds appeared to be paired, each pair was held in different aviaries for several months before the experiment was begun. The two extra females were held together.

TABLE 56

Feeding trials to establish if the presence of a bird feeding attracts it's mate to feed

Individual		Activity of mate	
		Not feeding	Feeding
♀♀	O	12	12
	S	15	0
	U	1	0
	W	3	5
	RR	4	3
	R	4	3
♂♂	O	8	14
	S	12	5
	U	8	0
	W	10	2
	RR	12	4
	R	13	4
Total		102	52

Rank Spearman Coefficient $r_s = 0.110$. Not significant

All of the birds were then separated from their mates a week before the experiment was commenced. One male was then placed in the Small Aviary and the following day a female was placed in the aviary with the male and observations made for one hour.

Recordings were made of the birds' activities and every 30 seconds the distance between the birds was noted. At the end of the observation period the female was removed and each successive day another female was introduced until all seven had been observed. The male was then replaced and the experiment repeated until all of the males had been tested with all of the females.

The results of this experiment are shown on Tables 57 and 58. Table 57 shows the number of times that certain displays were performed by the males towards the females (a list of these displays is given in Table 58). The observation periods have been divided into successive ten-minute intervals and the total number of times these displays were performed by each male in the ten-minute intervals are shown. Male A did not perform any displays towards any of the females at all during the experiment. It sat on a perch throughout the observation periods and did not move.

With the other males over half of the displays were performed in the first ten minutes after the introduction of the female (53%) and within 20 minutes 78% had been performed. There was no correlation between the number of displays performed in the first ten minutes and the average distance between the male and female during this period. There was no consistency in the amount males displayed to those females they had been paired with before the experiment. Males E and C displayed less while males B and D displayed more. Each male

TABLE 57

Total number of selected displays performed by individual males during series of pairing trials. A list of these displays is given in Table 58.

♂	A							E							B						
♀	A	C	D	B	E	F	G	A	F	C	D	B	E	G	D	C	B	A	F	E	G
Experimental period in 10 minute intervals:-																					
0-10	0	0	0	0	0	0	0	4	25	50	10	52	5	1	0	54	66	64	0	0	1
10-20	0	0	0	0	0	0	0	0	0	1	0	2	1	0	0	37	29	30	0	0	0
20-30	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	16	0	0	0	0
30-40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0
40-50	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	8
50-60	0	0	0	0	0	0	0	13	3	0	2	1	0	0	0	0	0	0	0	0	6
Total	0	0	0	0	0	0	0	17	29	51	12	57	6	1	0	91	114	94	0	0	15
Average distance (M) between ♂ and ♀ in first 10 minutes:	1.3	1.4	0.6	1.8	3.9	1.5	1.1	0.7	1.5	0.6	0.5	0.7	1.5	0.5	1.3	0.5	0.6	0.5	1.8	2.2	0.3

/cont'd

TABLE 57. Cont'd.

♂	D							C							Total
♀	C	B	F	D	E	A	G	A	D	E	B	C	F	G	
Experimental period in 10 minute intervals:-															
0-10	20	11	0	32	5	5	0	5	15	44	18	10	26	44	567
10-20	0	4	0	9	0	0	0	6	71	37	4	0	20	8	259
20-30	0	0	0	0	0	0	0	5	33	0	0	0	0	17	73
30-40	0	0	0	0	0	0	0	3	40	8	0	1	0	1	56
40-50	0	0	0	0	0	0	0	0	43	6	0	0	1	4	63
50-60	0	0	0	0	0	0	0	0	2	3	0	0	0	16	46
Total	20	15	0	41	5	5	0	19	204	98	22	11	47	90	1064
Average distance (M) between ♂ and ♀ in first 10 minutes:	0.6	0.7	1.3	1.0	1.1	1.0	1.2	0.9	0.7	1.6	0.7	0.8	1.8	1.1	

TABLE 58

Number of selected displays performed by individual males during series of pairing trials.

♂	♀	♂ activities																	♀ activities		
		Rbs	Head bob	Walk with head bob	Tail fan	Head wave	Bowing	Offering	SD 1	SD 2	SD 3	Ah-Ah 1	Ah-Ah 2	Ah-Ah 3	Bill touch	Feed female	Allopreen	Total	Agonistic display	Offering	
	A	1				3				8	1	3	1					17	6		
	F		1	3		3			4	6	7	5						29			
	C	19	3			2			4	6	10	3	3	1				51	1		
E	D		4			1			3	2	2							12			
	B	20	2	2	1				4	13	6	6	2	1				57	1		
	*E		3							1		2					✓	6		1	Allopreened for 26 mins.
	G	1																1	1		
Subtotal		41	13	5	1	9	0	0	15	36	26	19	6	2	0			173			
	D																	0			
	C	9	4				9		6	17	7	22	6	7	4	✓		91			Fed ♀ once.
	*B	66	5		1		2		11	5	3	10	1		10	✓	✓	114			Fed ♀ 9 times, allopreened for 3 mins.
B	A	64	1				7		1	12	3	1	1		4	✓		94	2		Fed ♀ 13 times.
	F																	0			
	E																	0			
	G	7							2		1	1			4			15		2	
Subtotal		146	10	0	1	0	18	0	20	34	14	34	8	7	22			314			

/cont'd

TABLE 58 Cont'd.

♂	♀	♂ activities																	♀ activities		
		Rbs	Head bob	Walk with head bob	Tail fan	Head wave	Bowing	Offering	SD 1	SD 2	SD 3	Ah-Ah 1	Ah-Ah 2	Ah-Ah 3	Bill touch	Feed female	Allopreen	Total	Agonistic display	Offering	
	C	9	1		1		2	3							4			20			
	B	2	9					1	2			1						15			
	F																	0			
D	*D	7		1	1				2	5	1	17	2	5		✓		41	3	1	Fed ♀ 3 times.
	E		5															5			
	A	1	3							1								5	1		
	G																	0			
Subtotal		19	18	1	2	0	2	4	4	6	1	18	2	5	4			86			
	A	1	3	3	1		3			4	3	1						19	6		
	D	28	4		1		1	3	2	25	17	63	59	1				204	8		
	E	13	2	1	1		2		7	33	17	14	4	3	1			98	10		
C	B	1						3	1	2		8	5	2				22	1		
	*C	2	1					1	1	6								11			
	F	9							9	21	2	2	4					47			
	G	13	3		1			1	24	22	3	16	5	2				90	7		
Subtotal		67	13	4	4	0	6	8	44	113	42	104	77	8	1			491			
Totals:		273	54	10	8	9	26	12	83	189	83	175	93	22	27			1064			

displayed more to some females than to others yet there was no concordance between the males concerning the females which were displayed to more than others (Kendell's Coefficient of Concordance Test, Siegel, 1956; $W = 0.20$; $0.70 > P > 0.50$). For example, male C performed 90 displays towards female G while male D performed no display at all to the same female.

The totals of the different displays performed by the males towards the females are shown on Table 58. In all cases regurgitation bobbing (rbs), the Squeak Displays and the Ah-Ah Displays form the largest part of the total displays performed (mean 86% with a range of 64-93%). The males differed in their responses to different females and between each other in the frequencies of different displays.

Only two of the males allopreened with a female and on both occasions it was with the female with which the male had been paired before the experiment was conducted. In one case (pair E) the female offered itself to the male and allopreening began 17 minutes after the female was placed in the aviary. In the other case (pair B) the female moved to the male and began allopreening after 44 minutes.

All of the four males which performed displays towards the females regurgitation bobbed, but not to every female. Only two males actually fed some of the females. After 4 minutes, male B fed the female it had been paired with and also fed females C (11 minutes after start) and A (6 minutes after start). Female A attempted to bite this male 11 minutes after the start and immediately after the male had fed it. The male displayed for a further four minutes, started chewing and appeared to take no further interest in the female.

Male D fed only the female it had been paired with and it was fed six minutes after the start and immediately after the female had offered itself for allopreening.

Females F and G were the two which were not paired before the experiment and female F ignored each male and sat quietly through each observation period. Female G ignored male D, offered itself to male B, gave several agonistic displays to male C and gave an agonistic display to male E in the first minute after the male had regurgitation bobbed.

The females were much less active than the males and the number of times the females performed agonistic displays towards the males, together with the number of times they offered themselves for allopreening are shown on Table 58. Here again there were differences in the response of each female to different males. Female A reacted agonistically to each male whenever it approached, except for male B yet female F ignored each male.

The indications from this experiment are that pair formation proceeds rapidly and that the male goes through a variety of displays most of which are grouped in the sexual category. For pair formation to have taken place the male must be able to approach the female to allow it to be fed, allopreened and, during the breeding season, copulated with. With the exception of male A, the males performed the majority of their displays towards the females in the first 20 minutes after approaching them. If the females rejected the males and appeared to take no part in the males activities, the males desisted and took no further interest in the females. There were variations in approach and in some cases male C persisted for longer periods than the others but the females reacted agonistically to it throughout its performance.

The males often appeared to approach the females tentatively during the displays, seeming to back away from the females before the females reacted - almost as if the males expected a rebuttal. This was also true of males observed in the field.

In the cases where allopreening took place the female initiated it by offering itself by actively approaching the male and starting to allopreen with it.

After this experiment had been conducted an attempt was made in the field to validate the theory that the male initiates pair formation. This was carried out with three pairs that each had a large nestling and the nests were close enough to be observed together. The males of two pairs and the female of the one pair were trapped one evening and held in cages away from the area of the nests. The nests were watched the following day to observe the reactions of the individuals. Around 0700 the male returned to the area of the nest alone and sat in a nearby tree calling intermittently. After remaining in the area for about three hours it flew off calling loudly. One of the females flew in at around 0800 and was accompanied by a male. The female sat in a tree near the nest hollow and as soon as the male landed it started a sequence of Squeak Displays and Ah-Ah Displays which lasted for 27 minutes. During this time the female sat quietly and on three occasions rejected the male with loud squawks and attempted to bite it. The male flew off after it ceased its displays. The female remained in the area of the hollow until around 1230 and flew off alone. During this period the female flew to the edge of the nest hollow twice and sat briefly but did not go in.

The other female returned to the nest area at about 1000 and landed in the nest tree. It was accompanied by a male which landed near the female. The female flew down to the edge of the hollow and the male followed landing close to the female and gave a series of Ah-Ah and Squeak Displays. The female squawked and attempted to bite the male. It flew to a nearby branch. The female went into the hollow and fed the nestling. It left the hollow and flew off followed by the male.

The experiment was terminated by releasing the other members of the pairs that afternoon after nearly 24 hours in captivity. Each pair subsequently fledged their nestling.

Additional information which lends support to the theory that it is the male that initiates pair formation was seen at Manmanning. Female OF was using hollow 43 and had laid two eggs. On one occasion OF was seen sitting alone in the nest tree. A male (not its mate) flew in and landed near OF on the same branch. The male immediately performed several Squeak Displays and one Ah-Ah Display towards the female who appeared to take no notice. The male flew off shortly after. The identity of the male was not known.

9.8.3 Agonistic behaviour. Studies of birds in the field revealed that there was little agonistic activity and that it was mostly associated with selection and preparation of nest sites. Around nest hollows, the resident female was dominant over other birds and in all other situations females were dominant over males. This seemed to be true not only with regard to a female's mate but also other males as well.

In order to investigate agonistic behaviour in aviary situations a pair (called old pair) was established in the Big Aviary and left there for several months. In early August a second pair (new pair) were introduced into the aviary at 1600, about two hours before dark. These two pairs had not been housed together prior to the experiment. During observations periods the birds' activities were recorded on a tape recorder. Observations were made from 0630-0800 for the next two mornings after the introduction and thereafter at approximately weekly intervals until 18 December. This period of observation was to establish if there were any changes in agonistic behaviour should the birds attempt to breed. Both pairs did attempt to breed and the old female laid between 18 and 26 September. The eggs failed to hatch and this attempt was abandoned by 6 November. This female relaid between 27 November and 4 December but these eggs also failed to hatch. The new female laid on 24 October and the nestling hatched on 22 November. The experiment was terminated on 18 December as this was the time when the pair would be absent all day if the attempt had taken place in the field. The nestling survived until early January when it died from unknown causes.

A dominance hierarchy was established within one hour of the new pair being introduced. The new female and male were dominant over the old female and male respectively and both females were dominant over the males. (The results of each bird's agonistic encounters with the other three birds are shown on Tables 59-62.) The results of the agonistic encounters usually consisted of the new female flying

TABLE 59

New female. Agonistic encounters with other three birds in aviary.*

Observation period	Agonistic encounters with:																				
	New ♂							Old ♂							Old ♀						
	Bill face	Bill face with gape squawk	PFC	PFC with squawk	Move to	Fly to	Total	Bill face	Bill face with gape squawk	PFC	PFC with squawk	Move to	Fly to	Total	Bill face	Bill face with gape squawk	PFC	PFC with squawk	Move to	Fly to	Total
10 Aug.					1		1		1			1	1	3						1	1
11 Aug.					2		2						1	1						5	5
12 Aug.													4	4						5	5
15 Aug.						2	2		1				1	2						2	2
21 Aug.	1						1		1					1		1					1
11 Sep.											1		1	2	1					2	3
18 Sep.					1	2	3													2	2
26 Sep.	1						1								Old ♀ in hollow						
2 Oct.															Old ♀ in hollow						
9 Oct.															Old ♀ in hollow						
16 Oct.															Old ♀ in hollow						
24 Oct.	New ♀ laid egg																				
30 Oct.	New ♀ in hollow for all but 14 minutes of observation														Old ♀ in hollow						
6 Nov.	New ♀ in hollow all time																				
20 Nov.	New ♀ in hollow all time																				
27 Nov.																					
4 Dec.															Old ♀ in hollow						
11 Dec.		1					1						1	1	Old ♀ in hollow						
18 Dec.															Old ♀ in hollow						

* New ♀ won every agonistic encounter.

TABLE 60

Old female. Agonistic encounters with other three birds in aviary.*

Observation period	Agonistic encounters with:																			
	Old ♂									New ♂									New ♀	
	Bill face	Bill face gape squawk	PFC	PFC with squawk	Move to	Move away	Fly to	Fly away	Total	Bill face	Bill face gape squawk	PFC	PFC with squawk	Move to	Move away	Fly to	Fly away	Total	Fly away	Total
10 Aug.																			1	1
11 Aug.		1							1										5	5
12 Aug.	3	1			6				10										5	5
15 Aug.	3	2							5										2	2
21 Aug.		1			1				2										1	1
11 Sep.																			3	3
18 Sep.					1				1		1							1	2	2
26 Sep.	Old ♀ in hollow																			
2 Oct.	Old ♀ in hollow																			
9 Oct.	Old ♀ in hollow																			
16 Oct.	Old ♀ in hollow																			
30 Oct.	Old ♀ in hollow																		New ♀ in hollow	
6 Nov.																			New ♀ in hollow	
20 Nov.																			New ♀ in hollow	
27 Nov.																				
4 Dec.	Old ♀ in hollow																			
11 Dec.	Old ♀ in hollow																			
18 Dec.	Old ♀ in hollow																			

* Old ♀ lost every encounter with new ♀
Old ♀ won every encounter with both ♂♂

TABLE 61

New male's actions in agonistic encounters with old male.

Observation period	Move to	Move away	Not move	Fly to	Fly away	Bill face	Bill face gape, squawk	Sq/ch stay	Sq/ch move away	Fly to, sq/ch	PFC	PFC, sq/ch	New ♀	Total	Old ♀	No. encounters won by new ♂
10 Aug.	2			3										5		5
11 Aug.				1		1								2		2
12 Aug.		1												1		0
15 Aug.								2	1					3		1
21 Aug.	2							7						9		6
11 Sep.								8						8		7
18 Sep.	2							20						22		15
26 Sep.	4			5				4		2				15	In hollow	15
2 Oct.	2			6				13		9				30	In hollow	25
9 Oct.	1			11				1		4				17	In hollow	16
16 Oct.				79				10		11				100	In hollow	99
30 Oct. *	3			56		1		2		8			In hollow for 46 mins.	70	In hollow	69
6 Nov.	1			2				14		8			In hollow	25		14
20 Nov.	4			9				9		3			In hollow	25		15
27 Nov.	2			46			2	14		38	3	5		110		98
4 Dec.				63				2		22	3	5		95	In hollow	92
11 Dec.	11			21			1	4		11				48	In hollow	46
18 Dec.	9			18		5	1	7		5		2		47	In hollow	33
Total	43	1		320		7	4	117	1	121	6	12		632		558

* On 30 Oct. new ♀ was out of nest hollow for 14 minutes. During that period 56 agonistic encounters between the ♂♂ took place. The remaining 14 took place during the remaining 46 minutes.

New ♀ won 558 (88%) of the encounters with old ♂; lost 2 (<0.3%); neither ♂ moved after 73 (12%).

TABLE 62

Old male's actions in agonistic encounters with new male.

Observation period	Move to	Move away	Not move	Fly to	Fly away	Bill face	Bill face gape, squawk	Sq/ch stay	Sq/ch move away	Fly to, sq/ch	PFC	PFC, sq/ch	New ♀	Total	Old ♀	No. encounters won by old ♂
10 Aug.					5									5		
11 Aug.					2									2		
12 Aug.	1													1		1
15 Aug.								2	1					3		1
21 Aug.					4			3	2					9		
11 Sep.		3	1		2				2					8		
18 Sep.			2		10			5	5					22		
26 Sep.		1			14									15	In hollow	
2 Oct.		4	3		20			2	1					30	In hollow	
9 Oct.			1		16									17	In hollow	
16 Oct.			1		99									100	In hollow	
30 Oct.			1		69								In hollow for 46 mins.	70	In hollow	
6 Nov.			5		9			6	5				In hollow	25		
20 Nov.		1	10		14								In hollow	25		
27 Nov.			11		96		1	1	1					110		
4 Dec.			3		92									95	In hollow	
11 Dec.		15	2		31									48	In hollow	
18 Dec.		1	14		32									47	In hollow	
Total	1	25	54		515		1	19	17					632		2

towards the old female who flew off before the new female got near it (Tables 59 and 60). After 12 August each encounter between the females occurred when the old female was investigating the entrance to one of the hollows in the aviary.

Both of the females won every agonistic encounter with the males (Tables 59 and 60) although the old female had only one such encounter with the new male. The new female usually moved or flew towards the males and they retreated (18 out of 25 encounters involved this action by the female [Table-59]). The old female used bill face (with or without gape and squawk) more (11 out of 19 encounters [Table 60]).

Agonistic encounters between the new female and the old male had ceased by 18 September. From that time on the new male would not allow the old male to get near the female (Table 61).

The results of the agonistic encounters between the males are shown on Tables 61 and 62 and illustrated on Figure 83. The only two encounters won by the old male were in the first five days after the introduction of the new pair.

The number of agonistic encounters between the two males remained relatively low until about one or two weeks before the old female laid. The number of agonistic encounters more than doubled and remained at this level until two or three weeks before the new female laid. At this stage the new male would not tolerate the old male near the new female. (The new male's mate was in a hollow incubating at this stage - Figure 83). From this time on the new male spent long periods chasing the old male up and down the aviary. The peak of the agonistic activity between the males was on 27 November when there were 110 encounters. Most of these

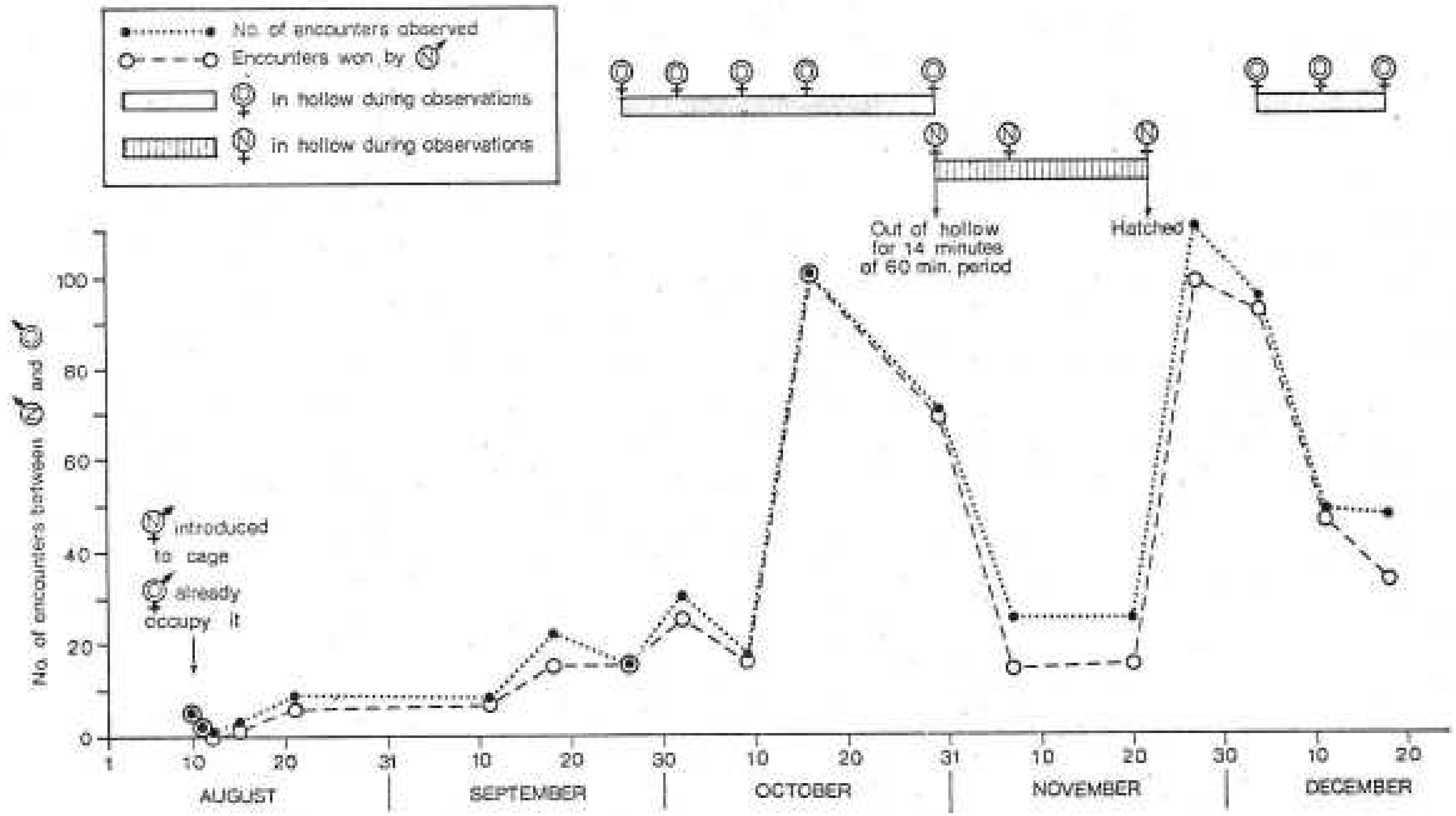


Figure 83. Agonistic encounters between new male N and old male O.

consisted of the new male flying towards the old male with or without a squeak/chatter and the old male flying off to the other end of the cage - the new male landing where the old male had been. It was obvious that the old male could not get far enough away in the aviary to escape from the new male.

There was a marked reduction in agonistic activity between the males when the new female laid and spent the observation period out of sight in the hollow (Figure 83). As soon as the new female appeared from the hollow the new male increased his harassing of the old male. For example, on 30 October, the new female was out of the hollow for 14 minutes and during this time there were 56 agonistic encounters. There were only 14 encounters between the males during the rest of the observation period, when the new female was back in the hollow.

This observation posed the problem that the presence or absence of a mate may alter the status of a bird and affect its dealings with other birds. In order to investigate this two pairs were placed together in the Small Aviary and observed for one hour each day in each of four days. Then in turn each bird was removed for four days and replaced, the next bird being removed. Every agonistic encounter between the birds was noted and the results of this experiment are shown on Figure 84. Here again the hierarchy was established immediately with female A and male A being dominant over the same sex of the other pair. Both females were dominant over the males.

The removal of the dominant female (A) reversed the situation between the males with male A winning only 3 out of 13 agonistic

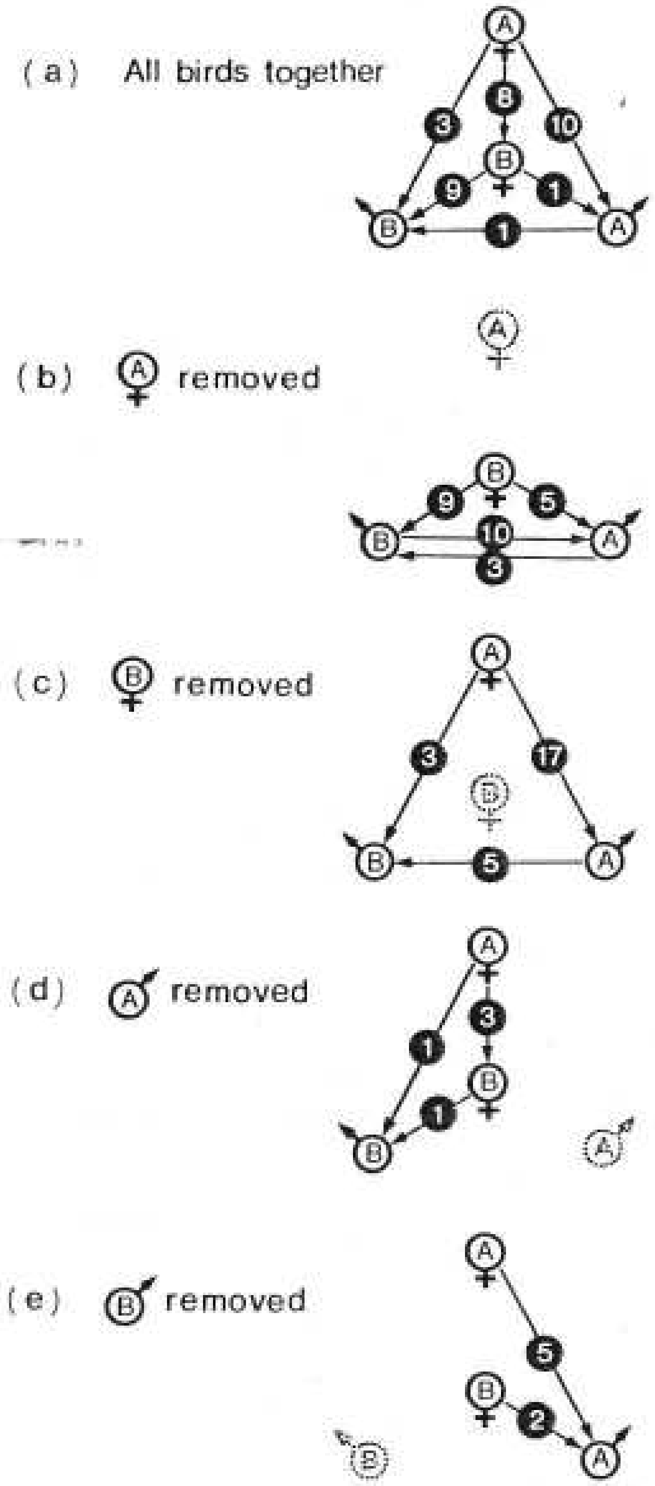


Figure 84. Results of agonistic encounters between two pairs in an experimental situation. Figures marked on arrows show the number of encounters between the individuals connected by the arrows, which points to the loser of the encounter.

encounters with male B. With the removal of female B the situation was again reversed. With the females, the removal of their mates did not affect the position in the hierarchy.

Aviary studies confirmed that females were dominant over males, a point which came out from field observations. The imposition of space limitations on the birds in aviaries means that under certain conditions the birds were not able to escape from each other leading to an increase in agonistic activities compared with the situation which exists in the field. With the results of the pair formation experiments it is predictable that the females are dominant over the males but there were no indications in the field of a hierarchy of the nature that was established in both cage experiments. The capacity to form such a hierarchy is obviously there (in view of the rapidity with which it was established) but there seems to be little need for such a hierarchy under most field conditions. In all situations, other than the defence of the area round a nest hollow the birds co-exist with very little agonistic interaction. It would appear that the two resources which the birds defend are: the area of the nest hollow and the other member of the pair, both resources which are vital to the ecology of the species.

9.8.4 Breeding studies. As mentioned earlier, the White-tailed Black Cockatoo had not been successfully bred in captivity prior to the start of this study. It was thought that there may be a space requirement for the birds to breed successfully and in order to provide a large enough cage should this be so, the Big Aviary was built. One pair was placed in this and the female laid two eggs which were infertile. The following year another pair was placed in the Big Aviary together with the first pair. This formed part of the experiment on agonistic behaviour. The old female laid twice but neither set of eggs hatched. The new female successfully hatched a nestling but it died at six weeks old. This pair were caught together at a nest site in the field and were a known pair. They were left alone in the Big Aviary but there were extensive earthworks carried out near the aviary during the breeding season and the pair made no attempt to breed. The old female had died earlier in that same year. The following year this new pair bred successfully but the nestling concussed itself on fledging. The pair were moved to the T-aviary and kept there with three other pairs. They made no attempt to breed. The following season the other three pairs were removed from the T-aviary and the new pair bred successfully and fledged one young. This bird broke its wing soon after fledging and died soon after.

Despite these very mixed successes, certain salient points emerge. Although all the birds used in the experiments were wild caught, known breeding adults, only two of the females produced eggs. Of these, only one produced fertile eggs - this female was the only one which was caught with her mate. The pair-bond is obviously important in allowing successful breeding and the known pair were the only ones with a bond of sufficient strength to allow breeding. The other birds were housed in similar conditions to the known pair yet they did not breed - the only apparent difference being the pair-bond.

As a result of this failure on the part of all but one pair no breeding studies were conducted on the aviary population.

10. Concluding discussion

The climate of the south-west corner of Western Australia is a regular one with a well-defined hot, dry period and a cold, wet one. Churchill (1968) found that there had been fluctuations in the ratios of marri, jarrah and karri pollen in the peat deposits of all swamp sites he examined in the south-west: he attributed this to the changes in distribution of the trees as a result of long term fluctuations of rainfall. Despite these fluctuations all three species have been present for much more than 10,000 years. It seems that the environment in the south-west has been stable for a long period. One by-product of this type of environmental stability is regularity of breeding and Davies (1979) has analysed nest records and breeding data from a number of species and shown that over 90 per cent of the clutches were laid between July and December. Data for individual species showed that although each species had a characteristic breeding period, it varied regionally and from year to year in the same place. The White-tailed Black Cockatoo is one of the many species that has adapted to this climatic pattern with a regular breeding season commencing two weeks either side of a mean date. It has also evolved an efficient social structure enabling it to be successful in a stable environment. The birds use the same area in which to breed each year but having remained in the one area for the five months required for breeding the birds move away and forage over a much wider area for the remainder of the year. Even during this non-breeding season the birds go to sites known to them and move from one to another throughout the season. The family group appears to be the most important unit in the social structure of the birds. The strength of the pair bond and the long association of parents and offspring confer several advantages on the species. The diet of the birds is varied (insect larvae, seeds and nectar) and the area over which they forage is large. The most efficient way to ensure that young birds find out what type of foods are eaten and what range to forage over, is to have a long association with it's parents so that it has time to learn by social facilitation. That it is a learning process involved was shown by McInnes and Carne (1978) who demonstrated that Yellow-tailed Black Cockatoos taken from the nest and hand-reared had no interest in logs infested with cossid larvae while adults collected from the wild immediately excavated the larvae. In the metropolitan area of Perth there are isolated pine trees which are attacked every year, probably by the same birds, and this is almost certainly a result of learning.

The breeding season is the only period when the birds are restricted to one site during the year and by moving away from these areas after breeding, the food supply is not over exploited. During the remainder of the year, the birds' habits of moving around in a nomadic fashion spreads grazing over a wide area and ensures some form of conservation of food supplies. The birds are quite destructive when feeding; chewing off branches and breaking them under their weight; and so any scheme of minimizing damage in one area would be beneficial. In addition, the dispersed breeding pattern with nests spaced out through the available resource also spreads the grazing more evenly. At Tarwonga, where birds were breeding in State Forest nests were spread throughout the forest and not concentrated in smaller areas. At Coomallo Creek, which is a natural "island" situation and provides the only breeding sites for considerable distances all round, there is a spacing of nesting birds as a result of the interactions between birds at the same stage of the breeding cycle. This effectively acts to limit the population.

Once the bond has been formed between a male and a female there are few displays associated with its maintenance. Allopreening and the feeding of the female by the male appear to be the way in which contact is maintained between the members of the pair all year. The fact that the pair are together all the time and that they are constantly in contact would decrease the number of displays or rituals needed to allow the male close enough to copulate during the breeding season. The lack of any form of greeting display is noticeable but the only time such a display might be necessary would be when the female is incubating. The ability of the birds to recognise a mate's call would eliminate the need for these ceremonies.

This species has evolved in a stable environment for a long period. The slow rate of reproduction, the longevity, the long period of immaturity, the site specificity for breeding and foraging, the long association between parents and offspring and the strong bond between the members of the pair are all consistent with this stability and have ensured that the species has been successful.

The social structure which enables the species to be successful in a stable environment places the species at a disadvantage during periods of rapid environmental change. Such changes are taking place within the range of the birds as a result of clearing for agriculture. Clearing of woodland in which the birds nest may lead to a concentration of birds in remaining nest sites and the increased agnostic interactions between females may lead to significant nesting failures. The long pair bonds and the attachment to specific breeding areas means that the birds will not disperse after disturbance and will persist in returning to the same sites and attempt to breed. The birds will persist until there are no areas nearby in which to breed or until they die out. The fact that the birds are long-lived and that they form large foraging groups outside the breeding areas may give rise to the belief that the size of the population is adequate and the birds are in no danger. This has already happened with the White-tailed Black Cockatoo. After the Forests Department began to establish large pine plantations on the Swan coastal plain, the numbers of black cockatoos visiting these pines during the non-breeding season seemed to increase rapidly. This was explained as being due to an increase in population as a result of a greatly increased supply of food. The results of this research indicate that this rapid build up of numbers in the plantations was not due to a natural increase in population size but could only be due to an increased concentration of existing birds as more and more learned of the source of food. With group sizes of 5,000-6,000 birds it appeared that the population was healthy. As some of the birds that formed this large aggregation came from areas where breeding success was too low for successful recruitment then the situation was masked by the large numbers.

Based on the distribution of breeding birds at Coomallo Creek, Manmanning and Tarwonga and applying these figures to the total area over which the birds are known to breed, some crude population estimates may be made. The total population of latirostris probably lies between 11,000 and 59,000 birds. Despite the large range of the estimate, if the larger figure is accepted, an aggregation of 6,000 birds in Gnangara pine plantation represents ten per cent of the total population.

The aim of this research was to gain biological information in order to set out some form of management guidelines for the control or conservation of this species. Faced with the fact that this species may be in need of conservation measures soon, what can be done about it? In order to preserve this species it is not sufficient simply to set aside one tract of land with both nest sites and an adequate food supply. The birds will only stay in the area to breed and then move off. Food must be available in other areas in sufficient quantity to supply the foraging groups during the non-breeding season. Pine plantations have proved to be ideally suited for this purpose but so have large tracts of sandplain heath in coastal national parks. The tenure of the national parks is secure and the food sources will be safe, but these areas do not satisfy breeding requirements. It is the breeding areas that are under more threat and suitable mosaics of native vegetation must be retained throughout the range of the species, if it is to survive.

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