CHAPTER 4

ABUNDANCE OF MALLEEFOWL IN NEW SOUTH WALES

4.1 INTRODUCTION

The aim of this part of the study was to estimate the density of Malleefowl in various parts of its range and use these estimates and data on distribution (from Chapter 3) to estimate the size of the Malleefowl population in N.S.W.

The unit used to measure abundance was an active nest (a nest which is built and maintained in spring and summer) and so an active nest indicates the existence of a breeding pair. Active nests and breeding pairs could be taken to be equivalent units of population size but exceptions to the rule and possible corrections to nests counts are discussed in section 4.4.1. Frith (1962a) used breeding pairs as the unit of population size in density estimates for his various mallee classes, but these numbers of breeding pairs appear to have come directly from counts of active nests.

4.2 METHODS

All survey sites selected for density estimates are described in detail in section 2.3, and reasons for their selection are in section 2.2.

4.2.1 Surveys of small areas between the Lachlan and Murrumbidgee Rivers

Mallee at six sites between the Lachlan and Murrumbidgee rivers were surveyed on foot. Surveys on foot were used because:

a. locations of all active nests were required for studies of breeding (see Chapter 6).

b. the vegetation was considered to be too dense and the sites too small for aerial survey techniques, and the experience of Frith (Frith 1962a) showed that surveys on foot were required to find all the nests.

Surveys were conducted in August/September: in 1981 only Pulletop was covered, in 1982 Pulletop, part of Buddigower, Mulyan and part of Yalgogrin were surveyed, and in 1983 Pulletop, part of Loughnan, Yalgogrin, Mulyan, part of Buddigower and Arcadia sites were surveyed.

From four to eleven people walked in line abreast, with one person near the centre of the line controlling the direction of travel by compass. People were spaced 20

- 30m apart depending on the density of the vegetation. Successive "sweeps" by the line were arranged with no gap between sweeps, to ensure a complete coverage of the ground.

The speed of survey varied with vegetation density, size and shape of the site, access within the site and experience of volunteers who assisted. Generally, 20 - 30ha per person per day could be covered.

All nests found were checked by an experienced observer to ascertain their condition. In August/September an active nest prepared for breeding was typically in a crater shape, filled with leaf litter, and had Malleefowl tracks, scats and scratch marks on the rim of the crater. Active nests were marked so they could be relocated; marking was by 'flags' in nearby trees or by a line scratched in the ground from the nest to a known feature in the vicinity.

4.2.2 Survey in central N.S.W. at Round Hill site

At Round Hill annual monitoring of nests was desired for management purposes that were not part of this study, but information on nest density could be collected at the same time. Nests were found by aerial surveys and annual relocation of nests was achieved by marking the nests so they were visible from the air.

Round Hill site was considered to be representative of much of the extensive mallee in the Ivanhoe - Cobar - Lake Cargelligo zone.

4.2.2.1 Survey blocks

The aerial survey was flown over Round Hill Nature Reserve and land adjoining the unmarked western boundary, the total area covered being 20,800ha. This area was divided into three blocks, using main roads, fire trails and the Parkes-Broken Hill railway line as boundaries visible to the pilot. It is all flat mallee country, except for small hills in the northern and eastern ends of the site.

4.2.2.2 Aerial survey

Nine aerial surveys were made: in August 1977, August and October 1978, August 1979, January and August 1980, February 1981, January 1983 and January 1984. Four surveys were flown in August because at that time mounds which were piled high with litter in preparation for breeding were more visible than at any other time. Three surveys, in October 1978, January 1980 and February 1981, were flown primarily to check on mounds seen prepared for breeding in the previous August, but unmarked nests were also marked in those surveys. The last two surveys, in January 1983 and January 1984, found a large number of the marked nests and monitored the number of pairs breeding there.

Because shadows from mallees make mounds very hard to see, air survey was restricted to the hours of 1000 - 1430 h in August, 0900 - 1530 h in October, and 0900 - 1530 h in January and February, Australian Eastern Standard Time.

An Aerospatiale Gazelle 341G helicopter was used throughout flown at about 76m above ground level, and about $90km.h^{-1}$. Because the aim was to cover as much of the area as possible, a regular pattern of transects was flown. In each block of the survey area a set of parallel transects about 400m apart was followed by a second set at right angles to the first. The direction of the transects was varied in subsequent survey periods. Parallel transects were flown on bearings, with the pilot adjusting for drift where possible. Flying evenly spaced transects in moderate winds was difficult for all pilots, because there are few prominent landmarks in the mallee.

An observer on each side of the helicopter covered a strip about 50m wide, but this strip was not defined by streamers. Thus in each set of parallel transects, 25% of the ground was seen, and two sets of transects overlapping at right angles was calculated to cover 44% of the ground. In nine survey periods, when nests were marked, there were about 10 complete sets of transects over each block.

The strips viewed were as close as possible to the aircraft, to give a view most free of obscuring foliage. With experience, observers could see nests through the canopy of mallee. In the first survey period both observers were inexperienced in aerial survey. In the second, both were experienced: in all others one was experienced and one inexperienced. The author flew in all surveys except in August 1980.

The total flying time for the nest-marking surveys was 74 h 33 min, spread over 22 days. Two surveys to monitor the number of breeding pairs in 1983 and 1984 took 17 h 44 min, over 6 days.

4.2.2.3 Permanent Nest Markers

Nests were marked, for subsequent identification from the air, with markers made from white or yellow, conical, fibreglass airport runway markers. These are resistant to weathering and visible from all directions in good light, and can be seen from up to 1000m altitude. They bore large black numbers, legible from about 70m. They were lowered from a helicopter at 5 - 10m altitude, into openings in the mallee, 10 - 60m from each nest.

The magnetic bearing and distance from the marker to the nest were recorded, to ensure that the nest could be easily relocated once the marker cone was seen.

4.2.2.4 Ground survey

Part of the site was sampled by surveys on foot to determine the proportion of nests that had been seen and marked from the air. The ratio of marked: unmarked nests could then be used to correct the air survey data to provide an estimate of absolute density of nests.

The methods of survey on foot at Round Hill were very similar to those described in section 4.2.1. Up to 11 people spaced 25m apart walked in line abreast with the direction of travel controlled by a person in the centre of the line. Thus sections of mallee about 275m wide and up to 6km long were sampled in transects across the site.

Two of the transects adjoined the railway line and the southern boundary firebreak to make navigation of the transect simple; two were located where a large number of nests were expected (from the results of air survey); and one was selected in a block of the site that was not sampled by any of the other 4 transects.

The surveys on foot occupied 23 h 35 min during 5 days in May 1981, and a total of 1414ha, 6.8% of the site, was seen.

Each nest found was checked by me and its condition recorded in a visibility class on a scale of 1 - 7, as follows:

1. Very small, very low nest, overgrown by grass or shrubs;
2. Low nest, with some shrubs or grass;
3. Medium sized mounds or shallow, very low crater shape;
4. Medium mound, raked over, or low crater shape;
5. High mound, raked or medium crater;
6. High crater;
7. High crater, leaves freshly raked in.

The two nests attended by Malleefowl in May 1981 were scored according to their February 1981 condition (when they were seen from the air); all other nests were assumed to have changed little in the previous years.

4.2.3 Experiments in aerial survey using two aircraft types

Experimental surveys were flown in June 1984 to test the suitability of a Cessna 206 aeroplane and a Gazelle helicopter for standard aerial survey of nests.

The design of the experimental survey tested the difference in the number of nests seen between time of day, observers and blocks while flying in the helicopter. A second trial tested the differences in number of nests seen between helicopter and plane, observers and areas.

4.2.3.1 Aircraft and Techniques

Surveys were flown with both aircraft using a stripwidth of 35m on each side and height of 76m above average ground level (maximum relief of sand hills estimated at 30m). The helicopter was flown at $80 km.h^{-1}$ and Cessna at $140 km.h^{-1}$.

Streamers that defined the stripwidth were tied to steel struts which projected from the front of the landing skids of the helicopter. Streamers were attached to the wing strut on the Cessna.

Stripwidth was checked by flying over an airstrip and then measuring the distance between points on the ground that had been in line with each streamer.

Surveys were flown over two small blocks in Wyperfeld National Park, each block having a high density of Malleefowl nests. Both blocks were marked on the ground by large sheets of white plastic placed 300m apart to form lines at each end of the block. One block, "Dattuck" had transects 2.8km long, and the other "Moonah" was 3.0km long.

Sixteen transects of identical length were flown over each block. The area observed on each transect was 9.8 ha at Dattuck block and 10.5ha at Moonah.

Four observers were used in the experiments. All were involved in management of conservation reserves containing Malleefowl.

Observers were trained for two days in the helicopter before the surveys. Electrical problems with the Cessna prevented more than short familiarisation flight before surveys from the plane. However, observation for the plane was essentially the same as from the helicopter, except for speed.

Each observer flew 16 transects at two different times of the day (early/late or close to midday) over both blocks in the helicopter. In the plane each observer flew 16 transects over each area.

4.2.3.2 Ground Survey to find nest density in the blocks

The ground marks for air survey and ground survey were organised by Joe Benshemesh, Zoology Department, Monash University.

Ground surveys covered 528ha or 96% of the Dattuck block and 537ha (85.5%) of the Moonah block. The Dattuck block had 66 nests, with 6 judged to be invisible from the air, because they were very small and lay directly under low obscuring foliage, giving an average density of 11.36 visible nests per square kilometre. There were 10 breeding pairs known in the block. The Moonah block had 55 nests, with 7 judged to be invisible from the air, to give a density of 8.94 visible nests.km^{-2}. In that block there were 15 breeding pairs.

4.2.3.3 Analysis

The numbers of nests seen per transect by each observer are shown in Tables 4.1 and 4.2. Over half the counts were zero, the remainder being no more than 4 nests per transect.

Data from 4 consecutive transects were lumped to produce 4 scores for each observer for each block for both times of day, for flights in the helicopter. Similarly there are 4 scores for each observer for each block for transects flown in the plane. These scores were converted to densities of nests seen for each area, and are shown in Table 4.3.

Analysis was by 3-way Analysis of variance of log transformed, log (x + 0.1), scores, using GENSTAT and is shown in Table 4.4. There were no significant differences in the number of nests seen between observers, time of day or area in the helicopter based surveys. There were significant differences ($P<0.05$) between results obtained from observers in the helicopter and plane, but no significant differences between areas or between observers when plane counts were compared to early/late helicopter - based counts.

Table 4.1 Number of nests seen per transect during aerial survey trials by helicopter (raw scores).

	DATTUCK AREA				MOONAH AREA			
	Venn	Moy	Brickhill	Muller	Venn	Moy	Brickhill	Muller
Counts early or late in day.								
	0	0	0	2	0	0	0	0
	0	0	0	2	0	0	0	0
	1	1	0	0	1	0	1	1
	2	1	1	0	0	0	1	2
	1	1	1	1	1	3	0	2
	0	1	0	0	0	1	1	0
	0	0	0	0	2	0	1	0
	0	0	1	0	0	0	2	0
	0	0	0	0	1	3	1	0
	1	0	0	2	0	1	1	0
	0	0	1	1	0	2	0	0
	1	1	0	0	1	1	1	1
	1	2	0	1	2	0	3	0
	0	2	1	0	0	2	0	1
	0	2	0	0	0	0	1	0
	1	2	0	1	0	0	0	0
	8	**13**	**5**	**10**	**8**	**13**	**13**	**7**
Counts near mid-day								
	3	4	0	0	0	0	0	0
	1	1	0	0	0	0	0	0
	1	0	0	2	0	1	0	0
	1	3	2	1	0	1	0	1
	1	0	0	0	1	1	0	1
	2	0	1	2	0	0	0	0
	0	1	0	0	1	0	1	1
	0	0	0	0	3	1	2	0
	0	1	0	1	1	3	2	0
	0	0	1	1	2	0	1	1
	0	0	1	1	1	1	0	0
	2	2	0	1	2	0	0	0
	1	0	1	1	1	2	1	0
	2	1	0	1	2	1	2	0
	0	1	0	1	0	1	0	0
	0	0	1	0	2	1	0	1
	14	**14**	**7**	**12**	**16**	**13**	**9**	**5**

Table 4.2 Number of nests seen per transect during aerial survey trials by fixed-wing aircraft.

DATTUCK AREA				MOONAH AREA			
Venn	Moy	Brickhill	Muller	Venn	Moy	Brickhill	Muller
0	1	0	0	0	0	0	2
0	0	0	1	1	1	0	1
0	0	0	1	0	0	0	0
0	0	0	0	1	1	0	1
2	1	0	0	1	0	0	1
0	1	1	1	1	0	1	0
0	0	0	1	0	0	0	0
0	1	0	0	0	0	0	0
1	0	0	0	0	0	0	1
0	1	0	0	0	2	1	1
0	0	0	0	0	0	0	0
0	1	0	0	1	2	0	0
0	1	0	0	0	0	1	1
0	0	1	0	1	1	1	0
0	0	0	0	0	0	0	1
1	1	0	1	0	1	0	0
4	**7**	**2**	**5**	**6**	**8**	**4**	**9**

Table 4.3 Density of nests seen (per 4 transects) during aerial survey trials. (nests.km^{-2})

HELICOPTER

	DATTUCK AREA				MOONAH AREA			
	Venn	Moy	Brickhill	Muller	Venn	Moy	Brickhill	Muller
Early / late counts								
	7.65	5.10	2.55	10.20	2.38	0	4.76	7.14
	2.55	5.10	5.10	2.55	7.14	9.52	9.52	4.76
	5.10	2.55	2.55	7.65	4.76	16.67	7.14	2.38
	5.10	20.41	2.55	2.55	4.76	4.76	9.52	2.38
Midday counts								
	15.31	20.41	5.10	7.65	0	4.76	0	2.38
	7.65	2.55	2.55	5.10	11.90	4.76	7.14	4.76
	5.10	7.65	5.10	10.20	14.29	9.52	7.14	2.38
	7.65	5.10	5.10	7.65	11.90	11.90	7.14	2.38
Mean	7.01	8.61	3.83	7.02	7.14	7.74	6.55	3.57
%seen	61	76	34	62	80	87	73	40

FIXED WING

	DATTUCK AREA				MOONAH AREA			
	Venn	Moy	Brickhill	Muller	Venn	Moy	Brickhill	Muller
	0	2.55	0	5.10	4.76	4.76	0	9.52
	5.10	7.65	2.55	5.10	4.76	0	2.38	2.38
	2.55	5.10	0	0	2.38	9.52	2.38	4.76
	2.55	2.55	2.55	2.55	2.38	4.76	4.76	4.76
Mean	2.55	4.46	1.28	3.19	3.57	4.76	2.38	5.36
%seen	22	39	11	28	40	53	27	60

Table 4.4 Analyses of variance to test for differences between the number of nests seen between observers, block, time of day and aircraft type.

VARIATE: LOGDENS

SOURCE OF VARIATION	DF	SS	SS%	MS	VR
Units Stratum					
Area	1	1.446	2.15	1.446	1.191
Time	1	0.141	0.21	0.141	0.116
Observer	3	0.943	1.40	0.314	0.259
Area.time	1	1.097	1.63	1.097	0.904
Area.observer	3	1.234	1.83	0.411	0.339
Time.observer	3	1.584	2.35	0.528	0.435
Area.time.observer	3	2.644	3.93	0.881	0.726
Residual	48	58.270	86.51	1.214	
TOTAL	63	67.358	100.00	1.069	
GRAND TOTAL	63	67.358	100.00		

GRAND MEAN 1.56
TOTAL NUMBER OF OBSERVATIONS 64

ANALYSIS OF VARIANCE

VARIATE: LOGDENS

SOURCE OF VARIATION	DF	SS	SS%	MS	VR
Units Stratum					
Area	1	1.175	1.10	1.175	0.725
Plane	1	11.047	10.34	11.047	6.823*
Observer	3	3.577	3.35	1.192	0.736
Area.plane	1	1.535	1.44	1.535	0.948
Area.observer	3	5.456	5.11	1.819	1.123
Plane.observer	3	5.125	4.80	1.708	1.055
Area.plane.observer	3	1.215	1.14	0.405	0.250
Residual	48	77.718	72.74	1.619	
TOTAL	63	106.848	100.00	1.696	
GRAND TOTAL	63	106.848	100.00		

GRAND MEAN 1.10
TOTAL NUMBER OF OBSERVATIONS 64

4.2.3.4 Correction Factors

Correction factors for counts from both aircraft can be calculated by comparing the mean of the density of nests seen by observers to the density of nests found by ground survey.

The density of nests at Dattuck was 11.36 nests.km^{-2} and at Moonah 8.94 nests.km^{-2}. Using the helicopter the mean density of nests observed by the four observers was 6.62 nests.km^{-2} at Dattuck (range 3.83 - 8.61) and 6.25 nests.km^{-2} at Moonah (range 3.57 - 7.74). Thus observers saw 58.3% of nests at Dattuck and 69.9% of nests at Moonah, a mean performance of 64.2% of nests present. A factor of 1.6 would correct the number of nests observed to an estimate of the absolute number of nests.

From the plane, the mean density of nests observed by four observers was 2.87 nests.km^{-2} (range 1.28 - 3.14) at Dattuck and 4.02 nests.km^{-2} (range 2.38 - 5.36) at Moonah, being 25.3% and 45.0% of nests present respectively, a mean performance of 35.1% of nests present being observed. From these results a correction factor of 2.9 would correct nests observed to an absolute count.

4.2.3.5 Choice of aircraft for survey

The results in section 4.2.3.3 and 4.2.3.4 show that counts from the helicopter were significantly different to those from the plane and about 1.8 times as large.

The helicopter was flown at a little more than half the speed of the plane, and because the same stripwidth was used in both aircraft, the helicopter is about half as fast as the plane as sampling the same amount of ground. Operating costs for the helicopter are about 4 times that of the plane (G. Dalitz pers. comm.) with the result that coverage of any area is about 8 times more expensive by helicopter than by plane.

Nevertheless, important reasons for using the helicopter were:

(a) the ability to return to a nest and observe closely from the hover to decide if a nest is "active" and so represents a breeding pair. Several attempts were made to return and check nests while flying in the Cessna. On all occasions the nest was lost to sight, being obscured by the wing on the turn. Only when a nest was near a large white transect marker would it be relocated by the pilot and observer working together.

If counts are to be made of Malleefowl populations, then it is essential that active nests are confirmed and counted, and this is near to impossible in the plane.

(b) better visibility. In the Cessna the wheels obscure the place where the nests are best seen.

(c) less eye fatigue due to lower speed of helicopter. This would allow more hours observing each day.

(d) less lateral movement (yaw) in the helicopter. Yaw causes difficulty to observers translating the strip width to the ground.

For these reasons the helicopter was used in aerial surveys described below.

4.2.3.6 Aerial survey: large areas in north-western Victoria, eastern South Australia and central New South Wales

An aerial survey sampled large areas of mallee in New South Wales, Victoria and South Australia, from 20 - 27th November, 1984.

The areas surveyed were:

In north-western Victoria

(a) Pink Lakes National Park, and an area adjoining to the east;

(b) Sunset mallee, a block mainly to the west of Rocket Lake;

(c) Wyperfeld National Park (eastern side) between Ginap track and the southern boundary;

(d) Wyperfeld National Park (west side - A) - north of 9 mile square track;

(e) Wyperfeld National Park (west side - B) - south of 9 mile square track;

(f) Big Desert Wilderness - from Murrayville track to South Australia border.

In eastern South Australia

(g) Dangalli Conservation Park - part of the "Hypurna" section.

In New South Wales

(h) "Tarawi" - a grazing property adjoining Dangalli C.P.;

(i) Pooncarie grazing properties 35km south-east of Pooncarie;

(j) "Lysmoyle" a grazing property 45km north-east of Hillston;

(k) "Nombinnie" a grazing property 75km north of Hillston.

All areas surveyed are shown on maps at 1:250,000 scale. Figures 4.1 - 4.6.

The survey was flown in a Gazelle helicopter using techniques developed in June 1984, and using the same observers.

Survey height 76m above ground level

Speed of $80kmh^{-1}$

Transect width 35m on each side of the aircraft.

4.2.4 Estimates of population size in each zone

The three methods of population survey (Sections 4.2.1 - 4.2.3) each covered habitats within a zone of the state (see Section 3.3.2). A population estimate can be calculated by the product of the density estimate for each zone and the estimate of habitat available (Section 3.3.2).

For four of the eight zones there was no direct estimate of density by survey. However, information from other sources can be used to provide a minimum density for two zones.

In the Condobolin zone, inspections have been made from the air of Woggoon Nature Reserve and land in the Parish of Tollingo, County of Cunningham, which are 12km apart and have a combined area of about $80km^2$. One active nest was seen in these two areas although inspections would have seen only about 20% of the ground surface. Thus a minimum density is 0.06 $pairs.km^{-2}$.

In the Goonoo zone, Mr. Terry Korn (pers. comm.) has found 8 active nests in Goonoo State Forest and land adjoining it in Coolbaggie Nature Reserve, which are a total area of $637 km^2$. These nests were found by driving along the network of tracks through the forest and flying over the reserve, and intensity of survey was estimated to be about 5%. These data produce a density of 0.25 active nests.km^{-2}, but that result is inconsistent with the small number of observations of Malleefowl in the area. A minimum density of 0.05 nests km^{-2} is expected, but the density could be up to 0.1 active nests.km^{-2}.

4.3 RESULTS

4.3.1 Densities in small areas between the Lachlan and Murrumbidgee Rivers

The results of surveys on foot are shown in Table 4.5.

In 1982 the mean density in the four sites surveyed was 2.42 active nests.km^{-2} while in 1983 the mean density in the six sites surveyed was 1.77 active nests.km^{-2}.

The density found by the 1983 surveys was lower because larger areas were covered and these areas included some lower quality habitat such as small rocky hills with open woodland vegetation. The mean density for all areas taken over the three years 1981 - 83 was 2.0 active nests.km^{-2}.

4.3.2 Density of nests found by air survey and nest marking at Round Hill site

In four years of aerial survey a total of 191 marker cones were used to mark at least 183 malleefowl nests (Table 4.6). The exact number of nests is not certain because eight nests were marked in 1980 and 1981 in areas burnt by bushfire in October, 1979, where marker cones could have been destroyed. In the western (fire-affected) block, seven marker cones have not been seen in any survey since the fire.

Table 4.5 Density of Malleefowl nests prepared for breeding found by surveys on foot.

Site	Area (ha)	Active nests	Density (nests.km^{-2})
1981			
Pulletop	145	3	2.07
1982			
Pulletop	145	2	1.38
Yalgogrin	376	17	4.52
Mulyan	287	1	0.35
Buddigower	100	2	2.00
Subtotal	908	22	2.42
1983			
Pulletop	145	2	1.38
Loughnan	256	3	1.17
Mulyan	287	1	0.35
Yalgogrin	558	20	3.58
Buddigower	180	4	2.22
Arcadia	386	2	0.52
Subtotal	1812	32	1.77
Total	**2856**	**57**	**2.00**

Table 4.6 Malleefowl nests found by aerial survey at Round Hill, 1977-84.

	Total flying time (h:m)	New nests found	Previously marked nests relocated	Total nests seen	Nests breeding
Aug. 1977	18:19	59	0	59	
Aug. 1978	16:49	74	52	126	
Oct. 1978	10:44	7	83	90	2
Aug. 1979	11:48	17	67	84	
Jan. 1980	1:00	0	16	16	3
Aug. 1980	12:01	25[A]	129	154	
Feb. 1981	5:52	9	102	111	3
Subtotal	74:33	191			
Jan. 1983	9:24	0	115	115	0
Jan. 1984	8:20	0	133	133	2

A Eight nests marked in 1979 wildfire area.

The ground survey at that site found 67 nests, of which 29, or 43.3%, were previously marked by aerial survey. Two of these nests were already prepared for the 1981 - 82 season.

The number and percentage of nests in each visibility class is shown in Table 4.7. Class 1 nests are highly unlikely to be seen from the air; if these are removed from the data, the percentage found by air survey is 45.3%. However, if only the more visible nests, which would include those being worked by malleefowl (i.e. classes 4 - 6) are considered, 25 out of 43 nests (58.1%) were seen from the air.

The total number of nests present was calculated from the air and ground survey counts by the method of Magnusson et al. (1978), which is equivalent to a Petersen estimate. If the number of nests marked was 183, and the ground survey area contained 67 nests of which 29 are marked, the entire study area contained 416 nests, at a density of 2.0km^{-2}. In August 1980, of 183 nests, 154 were seen; of these only three were used for breeding in the following summer. The above calculation gives 7.8 breeding nests, a density of only 0.04km^{-2}.

4.3.3 Density of nests found by aerial survey

The results of this survey, in Table 4.8, show the number and density of old, i.e. formerly used, nests. The number of active nests seen was too small for

Table 4.7 Malleefowl nests found by ground survey at Round Hill, May 1981.
Visibility classes described in section 4.2.2.4.

Visibility class	Number of nests found	Number of marked nests found	Percentage of marked nests
1	3	0	0
2	12	1	8
3	9	3	33
4	16	6	38
5	13	7	54
6	14	12	86
7	0	0	0
Total	67	29	43

Table 4.8 Aerial survey of Malleefowl nests: area covered, transect area, intensity, numbers seen and density of old nests.

Block	Area (km^2)	Transect area (km^2)	Intensity of survey %	No. Seen Unused	No. Seen Active	Density Old Nests km^{-2} ± S.D.
Pink Lakes	224	10.72	4.8	30	1	4.73 ± 0.76
Sunset	260	6.03	2.3	6	0	1.72 ± 1.22
Wyperfeld east	37	6.94	18.8	45	3	10.88 ± 0.97
Wyperfeld west A	52	5.58	10.6	8	0	2.83 ± 0.91
Wyperfeld west B	35	1.99	5.7	6	0[A]	5.59 ± 1.12
Big Desert	940	28.2	3.0	25	0[B]	1.42 ± 0.79
Dangalli	165	11.55	7.0	26	1	3.74 ± 0.86
Tarawi	180	10.92	6.1	10	0	1.28 ± 0.97
Pooncarie	408	19.74	4.8	26	0	2.02 ± 0.64
Lysmoyle	163	15.20	9.3	8	0	0.87 ± 0.79
Nombinnie	92	6.40	7.0	1	0	0.25 ± 1.22
				191	5	

A 2 active nests seen outside of transect area

B 1 active nest seen outside of transect area confident estimates of density.

The density of old nests was transformed by log (density +1) and analysed by analysis of variance using Genstat V (see Table 4.9). The standard error of difference between means was calculated.

Examination of the standard error of differences of means of densities of old nests indicates that there is no difference in density between Dangalli, Tarawi, Sunset, Wyperfeld (west A), Big Desert, and Pooncarie, all having low densities of old nests. The Pink Lakes and Wyperfeld (west B) areas have intermediate densities and Wyperfeld (east) has a high density of old nests.

This may be interpreted to mean that at times the habitat qualities of the Dangalli, Tarawi, Sunset, Wyperfeld (west A), Big Desert and Pooncarie sites have been similar and have produced similar low densities of breeding pairs of Malleefowl. Similarly Pink Lakes and Wyperfeld (west B) have had better quality habitat and previously higher densities of malleefowl than the former six sites. Wyperfeld (east) has had the highest quality habitat as shown by the highest density of old nests. This area still has a habitat quality sufficient for several active nests to be seen during the aerial survey over a relatively small area.

Table 4.9 Analysis of density of old nests seen by aerial survey.

Analysis of Variance

Y Variate:Log Density

	DF	SS	MS
Regression	10	29.47	2.947
Residual	95	40.13	0.422
Total	105	69.90	0.663

Predictions from Regression Model.
Y Variate:Density

	Mean	SE
Tarawi	1.28	0.97
Dangalli	3.74	0.86
Pooncarie	2.02	0.64
Pink Lakes	4.73	0.76
Sunset	1.72	1.22
Wyperfeld east	10.88	0.97
Wyperfeld west A	2.83	0.91
Wyperfeld west B	5.59	1.12
Big Desert	1.43	0.79
Lysmoyle	0.87	0.79
Nombinnie	0.25	1.22

The Nombinnie and Lysmoyle sites had very low densities of old nests.

4.3.4 Estimated population size for N.S.W.

In section 3.3 the distribution of Malleefowl in N.S.W. was divided into eight zones. The density estimates in each zone follow.

Lachlan - Murrumbidgee zone: Surveys on foot found 2.0 acitve nests.km^{-2}, but if the Yalgogrin site data are removed from Table 4.5, the density is 1.03 nests.km^{-2}, which is considered to be more typical for the zone. This adjustment is made because Yalgogrin is atypicical of all the small remnants of habitat that I have observed in the zone.

Ivanhoe - Cobar - Lake Cargelligo zone: The surveys at Round Hill site which lies in this zone found 0.04 active nests.km^{-2}. At Lysmoyle and Nombinnie sites there were very few old nests and no active nests found during aerial surveys, but Malleefowl are known to breed in the area (personal observations). Malleefowl also breed further north in the same zone, at Yathong Nature Reserve (H. Warren pers. comm.) so the density of 0.04 nests.km^{-2} is considered to be typical of the zone for lack of better data.

Scotia zone: Aerial surveys found no active nests in the Tarawi site, but if the data of Dangalli site (adjoining but in South Australia) are added, there is a density of 0.04 active nests.km^{-2}, and this result has been taken as typical for the zone.

Pooncarie - Balranald zone: Aerial surveys found no active nests in the Pooncarie site. However, Malleefowl are known from the area (see section 3.3.1 and Fig. 3.4) and young Malleefowl have been seen in the zone e.g. at "Wamberra" in 1986 (W. Dornbusch pers. comm.). Results of the aerial survey (section 4.3.3) suggest that Pooncarie habitats have been similar in quality to those at Tarawi because similar densities of old nests were found, but the Pooncarie site had all been burnt 10 years previously and the habitat at the site may have been unsuitable for breeding at the time of the survey. Therefore the density for the zone is low, and probably similar to the Scotia zone, and so a density of 0.04 active nests.km^{-2} is suggested.

Condobolin zone: The data in section 4.2.4 suggest that an estimated density of 0.06 active nests.km^{-2} may be applied to two areas of habitat in this zone, and, for lack of any other data, will have to be used as an estimate of density for all habitat in the zone.

Goonoo zone: The data in section 4.2.4 suggest that an estimated density of 0.05 active nests.km^{-2} may be applied to the zone.

Pilliga zone: There are no data on which to base an estimate of density for the zone. Reports of Malleefowl for the zone (Section 3.3.1) are very few and the density is probably 0.01 active nests.km^{-2} or less.

Upper Hunter zone: No attempt has been made to estimate the density of Malleefowl nests or area of habitat in this zone. The density is expected to be very low, and the population in the zone is expected to be quite small.

The products of these density estimates and the estimates of available habitat within the distribution are shown in Table 4.10. They give an estimate of 745 active nests in N.S.W.

Table 4.10 Estimated breeding population size by zone.

Zone	Density (active nests.km^{-2})	Habitat (km^2)	Population size (active nests)
Scotia	0.04	5650	226
Pooncarie	0.04	4700	188
Ivanhoe-Cobar Lake Cargelligo	0.04	3500	140
Lachlan-Murrumbidgee	1.0	90	90
Condobolin	0.06	400	24
Goonoo	0.05	880	44
Pilliga	0.01	3300	33
Upper Hunter	- - - no	estimate	- - - - - -
Total N.S.W.		18 520	745

4.4 DISCUSSION

4.4.1 Correction of active nests to breeding pairs

In all surveys of Malleefowl based on finding active nests the assumption is that every pair is breeding. This may not be the case in years with poor rainfall and hence poor food availability (Section 6.3.1). Data for the surveys on foot include all nests prepared for breeding in August/September and thus overcomes the problem of lack of breeding in the drought of 1982 - 83. The similarity of results for sites surveyed in two successive years also gives confidence in the results. The problem of pairs not breeding because of dry conditions did not apply to the aerial survey work as 1984 was generally suitable for nesting (J. Benshemesh, pers. comm.).

It could be assumed that every active nest represents a pair of breeding birds. Young birds may prepare a nest then abandon it without laying, or young or unattached males may maintain a nest without a female laying in it (Section 6.4.2). In 1983 - 84 six of 32 nests prepared and checked throughout the season subsequently did not contain eggs, leading to doubt about this assumption. If the sites used for breeding studies are typical of all Malleefowl breeding then 26 of 32 i.e. 81% of nests prepared for breeding in August/September represent adult pairs, while the remainder represent unpaired adult males or juvenile males. If a survey had been made in December then only 30 active nests would have been found, as 2 were abandoned in late September, so 87% of nests would represent adult pairs.

Therefore, to correct the number of active nests found to the number of pairs, the time of the survey relative to the breeding season must be taken into account.

The results for the breeding sites in the Lachlan - Murrumbidgee zone may well be not typical of all Malleefowl breeding as the sites are small, and are more likely to contain unpaired adults than extensive areas of habitat where birds could move over large distances to find mates. There are no other records of males maintaining nests without eggs being laid, so use of the data from those sites to postulate correction factors for all surveys must be doubtful, and probably should not be attempted. If the results of my nest surveys remain uncorrected and one active nest is taken to be equivalent to a breeding pair, this would not lead to errors larger than those already in the estimates. For accurate counts over small areas, a correction factor of about 0.85 may be suitable, depending on the time of survey.

4.4.2 Surveys on foot, Lachlan - Murrumbidgee zone

The survey areas covered were chosen for their known occurrence of Malleefowl (as they were to be sites of breeding studies (Chapter 6). Hence the density found would be higher than that expected if a random sample of remnant areas were surveyed. This means that the density of 2.0 pairs.km^{-2} is not typical for all such remnants (see Section 4.3.4).

The values given by Frith (1962a) for mallee classes II and III are 5.5 pairs.km^{-2} and 2.6 pairs.km^{-2}, for areas surveyed of 65.7km^{2} and 18.4km^{2} respectively. The differences between Frith (1962a) and this study suggest a decline in the population since the end of Frith's study.

4.4.3 Air survey and nest marking at Round Hill

The ground survey found nests at over twice the density given by the corrected air survey. I have assumed that the number of nests seen and marked from the air is independent of nest density when so few are seen, and so the ground survey only determines the ratio of marked to unmarked nests. Some ground-search areas were selected on the basis of a known, relatively high density of nests, to give a greater sample of nests for the ratio.

The difference between the densities of breeding nests found by the air and ground surveys illustrates the usefulness of the air survey in covering a larger survey area. When breeding nests are at a very low density, a small sample area of ground survey can give a large overestimate of the population.

Frith (1962a) found that ground surveys for nests in the poorest quality of "Class V Mallee" gave a density of malleefowl breeding pairs of $1.54km^{-2}$ in virgin mallee and $0.15km^{-2}$ in grazed mallee. Round Hill Nature Reserve has habitat similar to Frith's class V mallee, but the present survey gave a density of only 0.04 breeding pairs per square kilometre. As similar habitats could be expected to carry population densities of the same order of magnitude, these results suggest that malleefowl numbers have fallen since Frith's work.

The ratio of unused to breeding nests also suggests a decline in the population at Round Hill. Frith (1959) explains that territories may contain several temporarily unused mounds, and the birds may move from one mound to another in successive years, or use one mound for several years running. However, that behaviour would give a ratio far higher than three breeding nests to 154 old nests.

One disadvantage of the air survey at Round Hill is that it is dependent on a labour-intensive ground survey to develop correction factors. These are dependent on the amount of air survey time completed and are not immediately applicable, even with the same observers, at other study sites.

In the first survey the observers' performances generally improved through the survey, and often improved during each day. The best overall performance (boosted by the pilot's observing) was in August, 1978, when an average of 4.4 nests were found per hour; on the first day of the five-day period it was 1.28 nests per hour, and on the third day, 6.12 nests per hour.

My experience and results in the survey at Round Hill indicate that a survey to find and mark Malleefowl nests over a similar area could be compressed into one season, with about 15 days survey flying, between mid-October and mid-February. If this was split into closely spaced blocks of about 4 days flying it would optimize observer experience and minimise fatigue.

4.4.4 Aerial surveys over western and central N.S.W. sites

Frith's (1962a) figure for Malleefowl density in "Class V" mallee was 1.54 pairs.km^{-2} for ungrazed and 0.15 pairs.km^{-2} for grazed mallee. All of the mallee in N.S.W. covered by this survey would be considered to be Class V. The density "guestimate" of 0.04 pairs.km^{-2} for Scotia mallee (Tarawi and Dangalli sites) (Section 4.3.4) is thus well below the density expected from Frith's (1962a) study, and suggests a decline in the breeding population.

Again, as in section 4.4.3, the ratios of 36 old unused nests to one active nest in the Scotia mallee also suggests a decline in Malleefowl populations.

The Lysmoyle and Nombinnie sites had very low densities of old nests, but these two sites had much denser growth of grass (following a wet 1983 - 84 summer) than the other nine sites. Although there is no evidence for it, it is considered that this grass obscured some nests and gave a lower than expected observed density.

The extensive air survey work was also dependent on labour-intensive ground surveys to develop correction factors. This fact plus the high cost of helicopter flying time made the air survey work very expensive. The effort required in ground survey could be eliminated if air survey was only required for monitoring work, but monitoring may be most efficient when nests are marked.

4.4.5 Estimate for Goonoo zone

The density estimate for the zone is adjusted downwards from that indicated by the data in section 4.2.4. This was done because it is considered that the search method, i.e. driving along tracks to look for nests, gives an over-estimate of density. The over-estimate can be caused by Malleefowl tending to build nests on or near tracks or fencelines, where a break in the canopy allows sunlight to fall on the nest site.

4.4.6 Estimated Breeding population size

There is no way of knowing the errors associated with the estimates of population size without more extensive surveys. Even the surveys of small sites with high quality habitat gave densities with a range of one order of magnitude (see Table 4.5). Thus the estimate for the state population is at worst an educated conservative guess, but it is the best estimate available to date.

The estimate of 745 breeding pairs can not, at present, be related to total population size owing to a lack of life-table data. There is a great need for estimates of the numbers of juvenile birds present as some of them will form the future breeding pairs.

CHAPTER 5

DIET OF MALLEEFOWL

5.1 INTRODUCTION

Study of diet is necessary in any ecological study of an animal. The diet defines the species' role in the ecosystem, for example, herbivore, carnivore or scavenger.

The dietary study will determine the important foods of the species, and annual and seasonal changes in the foods eaten. Once foods of a species are known, the food availability in the habitat can be measured, and habitat requirements of the species more clearly defined. Knowledge of the diet and food availability can also allow estimates of habitat quality, which includes abundance and quality of food, shelter and breeding sites.

If the species under study is a herbivore, then the diet study will show the important food plants directly. Knowledge of the food plants and the response to manipulation or change in abundance through natural processes is essential if the species is to be managed.

Previous descriptions of the food of Malleefowl from gut samples (Chandler 1913, Lea and Gray 1935, Booth 1986) and observation of tame birds (Frith 1962a) are general descriptions of diet and have listed plant parts and species ingested. These descriptions have made no attempt to quantify or rank the important foods, or relate diet to daily maintenance requirements.

To study diet, the use of gut contents is precluded in endangered birds, and stomach sampling with emetics is unsuccessful in Malleefowl (D. Booth pers. comm.). Time constraints prevented habituation and observation of Malleefowl, so the methods used were the identification of food remains in scats.

5.2 METHODS

5.2.1 Collection and Treatment of Scats

Fresh scats were collected at occupied nest mounds at Yalgogrin on eleven dates at approximately fortnightly intervals over a six-month period, October, 1983 - March, 1984. The collections were made when I excavated nests to check egg laying and hatching. Fresh scats could only be found reliably at this time of the year when birds were regularly attending their nests. Fresh scats could not be found at any one nest on every visit, so all scats from all nests seen at Yalgogrin at any one visit were pooled for analysis. The nests were scattered throughout the site, and varied from 30m to 500m from wheat fields.

When found, the scats were usually encased in a white paste (presumed to be uric acid) formed into a rounded mass about 20mm long, which appeared to have been voided from the cloaca in a single lump. These lumps were moist if very fresh, but were usually dry when found. They were collected and stored in paper bags, and were air dried for several months before analysis.

Prior to analysis, the solid white material was broken away and the remaining scat weighed. Sub-samples of size 0.25g were broken from the scats which were very hard and compacted. Six sub-samples were taken from the scats collected on any one day, giving a total of 66 samples for analysis.

These samples were soaked in water for 24 hours to soften them so that all particles could be separated. They were then passed through a sieve with mesh size 0.6mm square. All particles retained in the sieve (mean number of particles = 64, range 8 - 292) were mounted on glass microscope slides using Stroyen's gum mountant.

Sieving of scats facilitates identification of food remains because it eliminates the mass of particles which are too small for identification. It may bias the quantitive evaluation of the diet if the frequency of particle sizes varies between prey species.

Scats were prepared to check for such a bias. Small pieces of scats from all dates of collection were pooled, soaked in water and passed through both 0.6mm and 0.25mm sieves. Particles retained in both sieves were mounted on glass slides in temporary mounts.

5.2.2 Reference Collection

A reference collection was prepared containing, wherever possible, leaves, flowers, fruits and seeds of all common plants on the site. Plant parts were stored in 70% alcohol until preparation. Leaf surfaces were obtained by boiling in concentrated nitric acid for five minutes followed by washing in water. The epidermal pieces were then mounted unstained. Buds, small flowers and soft fruits were squashed and mounted unstained. Petals of large flowers and small seeds were mounted whole, and larger soft seeds were cut up with a scalpel and the seed coat mounted. Hard seeds were broken into small fragments in a domestic food processor and the fragments then mounted. All plant parts were mounted in permanent gum mounts on glass slides.

Items in this reference collection were photographed microscopically with transmitted light, and black and white prints made at 80 times magnification.

A sample of scats was soaked, sieved and sorted to find any whole seeds or large pieces of seed. Several different seeds were then identified by N. Panich at the Seed Laboratory, Department of Agriculture, Sydney. Some species whose whole seeds were found in sorted scats were not found in the scats prepared for diet analysis.

5.2.3 Identification of Food Items

All particles prepared from the scats were examined at 40 times magnification using a binocular microscope with both incident and transmitted light. Incident light was necessary for opaque particles of stone, leaf, twig and bark and transmitted light showed cell wall patterns and cuticle sculpture. When necessary, particles were checked by examination under 100 times magnification. The area of every particle was estimated to the nearest 0.1mm square by visual comparison to a 1mm square grid on graph paper held under the slide. The number and area of each type of particle on each slide was recorded and is shown in Appendix 5.1. A total of 4204 particles were identified to determine the diet while 2860 particles were identified to check for bias in sieve size.

5.2.4 Calculation of Relative Intake Volumes

The absolute intake by volume could not be calculated as the number of scats produced by a Malleefowl per day is unknown. Also, many of the food items remained unidentified. The relative volume of intake could be calculated only for fruit and seed of seven plant species. However, these items comprised 52% of the area of all particles occuring on the slides.

Whole seeds and fruits of the species identified in the scats were measured and their surface area and volume calculated. Volume of intake was calculated by multiplying the area of seed coat seen in scats on the slides by the ratio of volume to area of the respective seed. The seeds of _Cassytha melantha_ and _Einadia hastata_ are held as single seeds within a fleshy fruit. Samples of these fruit were measured and their volume calculated. Volume of intake of these fruit was calculated by multiplying the area of seed coat recorded by the ratio of volume of fruit to area of seed of the respective fruit. It was assumed that the whole fruit and seed within it were ingested even though fruit coat of _Einadia_ was rarely found, and fruit coat of _Cassytha_ never found in the scats. This assumption was made on the observations that _Cassytha_ fruits were strong and sticky and the seed was not easily removed from it, fruit with seed removed was never seen, and whole unbroken seeds, remaining after fruit had rotted away were found commonly on the soil surface or raked into Malleefowl nests, indicating that they were not taken as food by Malleefowl. The _Einadia_ plants were only 5-20cm high so the fruits were always accessible to Malleefowl, and they were small, soft and succulent. The fruit coat of both species was probably too soft to occur as large fragments in scats after digestion.

Arthropod cuticle was found in every scat examined but fragments were limited to hard parts such as mandibles, leg segments and plates of cuticle. Unfortunately, arthropods had to be excluded from calculations of intake volumes because of the lack of identification of the species and their sizes.

5.2.5 Calculation of absolute intake requirements

From data on standard metabolic rate of Malleefowl it is possible to find the absolute food requirements. Seeds of three common species were collected and oven dried to provide data for such a calculation.

5.3 RESULTS

5.3.1 Foods Eaten

Table 5.1 is a list of all food items found in the scats. The list includes seed from at least 16 species, fruit from three species and other plant parts from an unknown number of species. As well, anthropods, sand and leaf litter were ingested. This list has been incorporated into a complete record of all known Malleefowl foods in Appendix 5.1.

5.3.2 Seasonal Variation in Diet

Table 5.2 shows the variation in the intake of food items between three two-monthly periods (October, 1983 to March, 1984). All but one of the seeds were consumed predominantly in one of the three periods, showing that Malleefowl were switching from one food source to another over the summer period. Casual observations showed that the food items were common in the scats when they were most common in the habitat. For example, free wheat *Triticum aestivum* seed was available in adjoining paddocks after harvest operations in December-January. *Cassytha melantha* was found in scats in all three periods despite it being apparently most commonly available in late summer.

Table 5.1 Food items identified in scats of Malleefowl at Yalgogrin October 1983 - March 1984.

Scientific name	Common name
Seeds	
Carthamus lanatus	Saffron thistle
Cassytha melantha	Mallee stranglevine
Einadia hastata	Saloop
Spergularia rubra	Sandspurrey
Triticum aestivum	Wheat
Acacia sp.	wattle
Galium sp.	bedstraw
Ranunculus sp.	buttercup
Solanum sp.	nightshade
Unidentified (7 species)	
Fruits	
Cassytha melantha	Mallee stranglevine
Einadia hastata	Saloop
Sida sp.	sida
Other plant material	
Fibers	
Leaf	
Petal	
Parenchyma cells	
Arthropod cuticle	
Sand	
Litter : bark, leaf, twig	

Table 5.2 Mean area (mm^2) of particles of food items per 0.25g of scat, from two-month periods, October 1983 to March 1984.

Food item	Oct-Nov	Dec-Jan	Feb-Mar
Seeds			
Carthamus lanatus	0	0.30	18.64
Cassytha melantha	1.78	0.90	1.32
Einadia hastata	0	0	1.72
Triticum aestivum	0	19.70	2.07
Acacia sp.	0	4.75	1.63
Ranunculus sp.	1.85	0.05	0
Solanum sp.	0	0	3.81
Unknown 6	0.08	1.09	0
7	0.08	1.36	0.38
12	0	0	0.26
14	0	0	0.47
15	0	0	0.27
16	0	0	0.43
18	0	0	0.26
Other seeds	0.25	0.17	0
Fruit			
Einadia hastata	0	0	0.08
Sida sp.	0.03	0	1.12
Fibres	3.44	0.29	0.20
Petal	0.32	0	0
Leaf	0.42	2.12	0.16
Unknown 1	11.83	3.05	0
Other unknowns	3.46	1.67	4.22
Arthropod cuticle	4.47	7.63	8.97
Sand	1.61	2.02	0.25
Litter	5.77	2.25	0.08
Number of samples	N = 12	N = 24	N = 30

The area of anthropod cuticle increased during the summer. The difference in the area of cuticle between the three periods was tested by analysis of variance and found to be significant at the 6% probability level. The lack of a significant result is due to high variability in the area of cuticle between samples.

5.3.3 Food Selection

Table 5.3 divides all the plants identified at Yalgogrin by their seed size. It shows the frequency with which those plants are food plants for Malleefowl. The frequency increases with increasing size of seed up to the 6-10mm size class where it is 100% and then it declines. The data indicates that Malleefowl are selecting the larger seeds in preference to the smaller seeds.

Appendix 5.2 lists, for all plants identified, a rating of their abundance (based on casual observations over two years of fieldwork) and the size of the seed or fruit produced. It shows that Malleefowl are selecting the larger seeds and/or fruits which are commonly available. Some large seeds, of Myoporum desertii and Billardiera versicolar are rare and so either did not appear in the scats or are avoided. The largest seeds available, of quandong Santalum acuminatum, are probably too hard and large to be eaten, although it is recorded as a food item in Cleland (1952).

Table 5.3 Frequency with which plants of given seed size are food plants of Malleefowl at Yalgogrin.

Seed length (mm)	No. of plant species	No. of food plant species	Frequency (%)
0 - 2	35	1	2.9
2 - 4	14	5	35.7
4 - 6	8	2	25.0
6 - 10	2	2	100.0
10+	3	1	33.3
	62	11	17.7

5.3.4 Relative importance of food items

Appendix 5.3 records the number and area of all particles sampled in the scats.

Table 5.4 is a summary of those data, and contains the number, area and frequency of particles of each item. For the seven species of seed identified Table 5.5 gives their size, shape, surface area, volume and volume to area ratio. Table 5.6 shows the relative volume of intake of the seven identified seeds. Cassytha melantha was consumed in the greatest amount, with Triticum aestivum, Einadia hastata and Carthamus lanatus all in similar volumes to each other but about half that of Cassytha. The small seeds of Solanum sp. and Ranunculus sp. were consumed in relatively minor volumes.

5.3.5 Effects of sieve size on analysis

The results presented are from data collected on particles that did not pass through a 0.6mm square mesh sieve. Table 5.7 is the numbers of particles found remaining after a sample of scats was put through both a 0.6mm sieve and a 0.25mm sieve. This table shows that on a number of particles basis, some food items especially the soft plant parts were more commonly found in the 0.25 mm sieve that the 0.6 mm sieve, and so they would be more common in the diet that as shown in Table 5.4. Further, Table 5.8 presents data on a sub-sample of particles remaining in the finer sieve which were

Table 5.4 Summary of items found in 66 samples of 0.25g of Malleefowl scat.

Item	No. of particles	%	Area of particles (mm^2)	%	Frequency (%)
SEEDS					
Triticum aestivum	603	14.3	535.8	18.1	18.2
Cassytha melantha	173	4.1	82.4	2.8	34.2
Einadia hastata	66	1.6	51.6	1.7	16.6
Carthamus lanatus	910	21.6	566.4	19.2	18.2
Acacia sp.	239	5.7	163.0	5.5	28.8
Solanum sp.	163	3.9	114.2	3.9	9.1
Ranunculus sp.	24	0.6	23.5	0.8	9.1
Unknown 6	28	0.7	27.9	0.9	12.1
Unknown 7	63	1.5	45.1	1.5	21.2
Unknown 12	10	0.2	7.9	0.3	3.0
Unknown 14	16	0.4	14.0	0.5	3.0
Unknown 15	10	0.2	8.1	0.3	6.1
Unknown 16	21	0.5	13.0	0.4	7.6
Unknown 18	7	0.2	7.6	0.3	4.5
Others	7	0.2	7.1	0.2	9.1
		57.0		57.3	
Fruit coat					
Einadia hastata	4	0.1	2.5	0.1	1.5
Sida sp.	51	1.2	33.8	1.1	7.6
Other plant material					
Fibres	283	6.7	53.9	1.8	40.1
Petal	2	0.1	3.8	0.1	3.0
Leaf	76	1.8	60.6	2.1	13.6
Unknown 1	339	8.1	215.3	7.3	22.7
Unknown (Others)	220	5.2	208.0	7.0	65.2
		23.2		15.8	
Arthropod cuticle	712	16.9	505.8	17.1	100.0
Sand grains	51	1.2	75.3	2.5	27.2
Litter	126	3.0	125.6	4.3	40.1
Total	4202	100.0	2952.2	99.8	

Table 5.5 Shape, size, area and volume of fruits and seeds identified in Malleefowl scats from Yalgogrin.

Species & form	Shape	Size (mm)	Area (mm^2)	Volume (mm^3)	ratio V/A
Seeds					
<u>Carthamus lanatus</u>	rectang. prism	3x2x2	32	12.5	0.4
<u>Cassytha melantha</u>	sphere	6(dia)	113	113	1.0
<u>Einadia hastata</u>	sphere	1(dia)	3.1	0.5	0.16
<u>Triticum aestivum</u>	ellipsoid	6x3x3	56.5	28.3	0.5
<u>Acacia</u> sp. <u>(?hakeoides)</u>	elongate disc	4x3x2	18.8	18.8	1.0
<u>Ranunculus</u> sp.	oval disc	1x1.5x0.2	2.4	0.24	0.1
<u>Solanum</u> sp.	oval disc	2x1x0.5	3.1	0.8	0.26
Fruits					
<u>Cassytha melantha</u>	sphere	11(dia)	380	697	6.2*
<u>Einadia hastata</u>	sphere	3(dia)	28.3	14.1	4.6*

* Volume/Area ratio calculated for volume of fruit over area of seed.

Table 5.6 Volume of intake of identified seeds and fruits calculated from area of seed coat found in scats.

Food item	Area seen in scats (mm^2)	%	Volume of intake (mm^3)	%
Carthamus lanatus - seed	566.4	36.8	226.6	15.8
Cassytha melantha - fruit & seed [A]	82.4	5.4	510.9	35.5
Einadia hastata - fruit & seed [A]	51.6	3.4	237.4	16.5
Triticum aestivum -seed	538.8	35.0	267.1	18.6
Acacia sp. - seed	163.0	10.6	163.0	11.3
Ranunculus sp. - seed	23.5	1.5	2.6	0.2
Solanum sp. - seed [B]	114.2	7.4	29.7	2.1
	1539.9		1437.3	

A. Area of seed coat measured in scats, converted to volume of intake of fruit and seed, on the basis of 1 seed to 1 fruit.

B. Species not known, so number of seeds per fruit or fruit size is not known.

identified only as "plant cells" under 40 times magnification. At 100 times magnification these were identified as various cell types, the majority being parenchyma cells from within plant tissues. The numbers of particles counted and shown in Tables 5.7 and 5.8 cannot be used to correct counts or areas of particles summarised in Table 5.4 because these parenchyma cells are from within plant tissue and are not surface cells and so cannot be corrected for surface to volume ratios.

However, they do indicate that plant material (i.e. leaf contents, buds or soft stems) is a more important part of the Malleefowl diet than is apparent from the data in Table 5.4. Further support for this idea can be found in the fact that the items called "fibres" in Table 5.4 appeared to be vascular bundles, such as veins in leaves or stems which remained after digestion. Fibres were found in 40.1% of scats and unknown plant cells were found in 65.2% (Table 5.4) and thus green plant material would be more important in the diet than is indicated by the percentage of area of particles, being 1.8% and 7.0% respectively. "Fibres" were found more commonly in scats in Spring (Table 5.2), but unknown plant material was found in scats from the whole 6 months.

Table 5.7 Numbers of particles from scats retained by sieves of two mesh sizes. Examination under 40x magnification.

Particle type	0.6 x 0.6 mm sieve Number	%	0.25 x 0.25 mm sieve Number	%
Arthropod cuticle	69	18.9	434	14.6
Acacia sp.	9	2.5	189	7.2
Carthamus lanatus	172	47.1	254	2.1
Cassytha melantha - seed	0	0	15	0.6
Einadia hastata	2	0.5	2	0
Fibres	24	6.6	261	9.5
Plant cells	60	16.4	1655	63.9
Sida sp. - fruit	14	3.8	34	0.8
Spergularia sp. - seed	0	0.0	9	0.4
Stellate hairs	0	0.0	5	0.2
Unknown 6	1	0.3	1	0.0
Unknown 11	1	0.3	1	0.0
Unknown 12	5	1.4	17	0.4
Unknown 15	0	0.0	4	0.2
Litter fragments	8	2.2	8	0.0
	365	100.0	2860	

Table 5.8 Number and desciption of fine particles in a sample of "Plant cells" category shown in Table 5.7.
Examination under 100x magnification.

Description	Number	%
Triticum aestivum - seed coat	5	3.2
Unknown 1	28	17.9
Unknown seed coat 7	9	5.7
Fine seed 0.5mm long	2	1.3
Generalised plant cells		
- elongated	22	14.1
- packed, yellowish	57	36.5
- loose spheres, brown	7	4.5
- packed spheres, pale	15	9.6
Others	11	7.1
	156	100.0

5.3.6 Absolute intake

The standard metabolic rate (SMR) for Malleefowl is 0.52 ml $O_2.g^{-1}\cdot h^{-1}$ (Booth 1985). For a 2kg bird, SMR = 117 kcal. day^{-1}.

Assuming that seed has $4kcal.gm^{-1}$ (dry weight) and 80% digestibility then the metabolisable energy in seed would be $3.2kcal.gm^{-1}$ and a 2kg Malleefowl would require 36.6gm of dry seed per day. For wheat *Triticum aestivum*, 36.6gm is 1289 seeds, for stranglevine *Cassytha melantha* it is 300 seeds, and for saffron thistle *Carthamus lanatus* 2245 seeds per day.

5.4 DISCUSSION

5.4.1 Limitations of Methods

The use of scat analysis to determine the diet of Malleefowl has some strong limitations. The gizzard of these birds is very strong and hard seeds (e.g. *Carthamus lanatus*) are broken into many small pieces. Therefore, soft items are ground into very fine particles and so are not detected or not identified by the methods used. Lerps are eaten by Malleefowl (J. Benshemesh, D. Priddell pers. comm.) and the lerp cases would be dissolved in the gut and not detected while the insect cuticle would not be differentiated from other cuticle remains.

The digestion process in the gizzard and gut breaks the seed up and/or abrades the seed coat surface. The distinctive patterns on the seed coats are used for identification of many seeds (N. Panich, pers. comm.) and therefore the identification of pieces of abraded seed by comparison with whole seed in reference collections can be very difficult. The small size of particles leaving the gut also causes problems with identification. Particles of plant material examined under high power contained as little as 50-100 cells which was insufficient to provide distinctive epidermal surfaces.

The collection of scats was only feasible for six months of the year when birds were attending breeding mounds. Thus the results only indicate the diet of adults for the late spring, summer and early autumn period.

5.4.2 Analysis

There are several methods of recording abundance of dietary items in guts or scats. Ideally, the volume of intake of each food type should be known, and this can be calculated from daily energy requirements and data on relative volumes of intake.

The relative volume of intake could not be calculated in this study because of a lack of identification of seeds, arthropods and ingestion of soft plant material that did not have identifiable epidermal surfaces. Thus the number, area and frequency of items in scats are the only data available for comparisons of relative importance of foods.

The number of particles is proportional to their digestibility, and surface area to volume ratios and so it is an unsuitable measure of relative food intake. A better measure of food intake is the area of particles, as it can be corrected by volume to surface area ratios for each food item, to provide the relative volumes of intake of food items. Other studies have used the frequency of observation of the items in the samples as a measure of importance of food items.

Table 5.4 shows the abundance of items as numbers of particles, area and frequency. There are large differences between the apparent relative importance of items when determined on the basis of area rather than frequency. Frequency inflates the value of small items eaten regularly relative to large items infrequently ingested. For example, arthropod cuticle was found in every scat (frequency 100%) but only comprised 17.1% of the total area of particles. "Fibre" was ranked third most frequent, occurring in 40.1% of scats, but ranked number twelve in area, being only 1.8% of total area.

5.4.3 Food Value

The results presented in 5.3.1 suggest that larger seeds are selected by the Malleefowl in preference to the smaller seed. The selection on size could be expected because of the efficiency of collecting larger seed, with a much larger relative volume, than small seed if both sizes have similar costs of collection.

Seeds and fruits are probably selected on the basis of quality as well. *Einadia* fruits are one of the smaller items eaten, but they are succulent and so would provide water which may be a valuable commodity in the harsh summer climate.

5.4.4 Summary of diet

This study of diet shows the Malleefowl to be predominantly granivorous with considerable amounts of herbage and arthropods in the diet. At Yalgogrin they make use of the common large seeds from *Cassytha*, wheat and saffron thistle as well as a variety of other seeds.

The wheat, saffron thistle and four other species of seed identified in the scats are annuals and seed production would be controlled by the previous winter-spring rainfalls. The amount of herbaceous food available would also be directly controlled by the previous cool season rainfalls. The most important seed in the diet is from *Cassytha* which is a vine, parasitic on *Eucalyptus* and *Melaleuca*, most commonly seen on 7-15 year old mallee regrowth.

5.4.5 Comparison with other studies

Generally, this study agreed well with the results of Frith (1962a) and Booth (1986). I recorded new food items for Malleefowl, but that is to be expected when a generalist forager is studied in new locations and habitats.

Booth (1986) had only two gut contents, but found a large number of plant and animal species in them. As in my study, seeds were prominent in the diet, including seeds from the family Chenopodiaceae and *Cassytha* _melantha_, and green foliage, litter fagments and sand were found to be ingested. Frith (1962a) did not mention Malleefowl ingesting litter or sand; this absence could be expected from his diet study which was by observation. Frith (1962a) did note the importance of seeds in the diet, although at his site leguminous seeds were commonly eaten, probably because the were more available in the habitat than other seeds of a similar size. Another similarity was that Frith (1962a) described the importance of herbaceous food in the diet in winter and spring.

Invertebrates were described as being a relatively minor part of the diet by Frith (1962a) although 17% of feeding observations were of insects being eaten, while Booth (1986) found that insects comprised 5.5% dry weight of one crop contents. My study invertebrate remains in every scat (100% frequency) but they accounted for 17.7% of surface area of all food particles. The variation in levels of invertebrates in the diets between the three studies can be ascribed to he various methods used rather than any great differences in diet at the three locations studied.

This study found that Malleefowl appeared to be selecting the larger seeds available in the habitat, while Frith (1962a) describes captive Malleefowl as preferring small seeds. It is probable that in capivity, with abundant food, Malleefowl may select seeds for quality rather than efficiency of collection, which would be expected in the wild. Frith (1962a) describes Acacia hakeoides seeds as 1mm in diameter, where as I found them to be up to 4mm long.

None of the studies have been able to accurately divide the total dietary intake into each food component. A better definition of diet would be possible by a combination of observation of intake and then calulation of volume or energetic value of that intake.

CHAPTER 6

FECUNDITY AND BREEDING SUCCESS

6.1 INTRODUCTION

Malleefowl are endangered in N.S.W. because their habitat has been removed at a rate which cause for concern. This removal of habitat may be deduced from previous studies of the status of Malleefowl (Griffiths 1954; Frith 1962a) and the results presented in Chapter 3.

Frith (1962a) found that in uncleared, ungrazed habitats Malleefowl fecundity was high and fox predaion of eggs was insufficient to cause the population to decline. Therefore, it could be assumed that in large expanses of uncleared, ungrazed habitat Mallefowl population sizes should have remained relatively stable. However, the aerial surveys described in Chapter 4 suggested that populations in such areas had, in fact, declined from levels estimated by Frith (1962a).

The results in Chapter 4 also show that in small protected sites, such as Pulletop, the breeding population has declined fom the size measured by Frith (1959).

Knowledge of fecundity and breeding success is required for development of a life table that can be used to identify sections of a population that may be responsible for low population sizes.

The aims of this part of the study were to measure fecundity and observe the fate of eggs and compare the results with those Frith (1959) and Booth (1985).

6.2 METHODS

6.2.1 Nest searches

Nests were located by four to eleven people walking in line abreast using methods similar to those of Jones (1963). Searches were conducted in August and September of each year to find nests prepared for breeding prior to egg laying. In 1981, Pulletop site was searched and three nests found.

In 1982 searches covered Pulletop, Buddigower, Mulyan and part of Yalgogrin sites. A nest known at Arcadia site was included in the nests studied in the following summer.

In 1983, searches covered all previous areas plus Loughnan, Arcadia and all of the bush area at Yalgogrin, a total area of 1812ha.

6.2.2 Nest inspections

During the breeding season, each nest that had been prepared for breeding was inspected at fortnightly intervals from mid-October until it was abandoned at the end of the season, which varied from February to April. Fifteen nests were isolated by local flooding in January 1984, resulting in a time span of 4 weeks between two visits. (These nests were Yalgogrin Nos. 12-20 and all nests at Mulyan, Arcadia and Buddigower).

At each inspection, the nest was excavated until the eggs were exposed. Eggs were labelled with a number written on the shell when they were found for the first time. Subsequently, eggs in the nests were scored in one of the following categories:

1. missing, cause unknown;
2. missing, presumed collected by humans as many eggs were missing simultaneously and there was no evidence of animal predators;
3. eaten by fox, recognised by a description in Frith (1959);
4. broken by observer or other human interference;
5. broken by malleefowl, determined by claw-sized punctures in the top of the egg;
6. dead, surrounded by rain-soaked nest material;
7. hatched and the chick found dead in the nest; or
8. hatched and chick presumed fledged.

Eggs that remained when the nest was abandoned were broken open to see if chicks had developed. Eggs that only contained a watery fluid and no yolk were considered infertile. Eggs that contained a partly developed chick had been laid too late in the breeding season and there was insufficient time for incubation. No reason could be attributed to the failure of some eggs to hatch; causes may have included incorrect temperature regulation or infection of the egg by micro-organisms.

It was impossible to determine accurately the outcome of every egg. For example an egg that was punctured by a malleefowl during nest temperature regulation and eaten by a fox before the next inspection by the observer, would be recorded as fox predation. Before excavation of the nest, the mound shape was recorded, as was the presence of adults at the nest or signs of recent activity. These records were used to estimate the date of nests being abandoned.

6.2.3 Removal of eggs

Late in the breeding season of 1983-84 it was apparent that many eggs would remain in the nests when the adults abandoned them. Thirty-two eggs were collected on 22 and 23 March 1984 and they were artifically incubated at Taronga Zoo, Sydney. Chicks that hatched were sexed by internal examination, pinioned and raised to start a captive breeding programme. The date of hatching of each of the 21 fertile eggs in the 32 collected was recorded and compared to the estimated date of abandonment of the nests from which they came. Those eggs that hatched in captivity before the mound from which they were taken was abandoned were considered as having hatched from the mound.

6.3 RESULTS

6.3.1 Fate of nests prepared

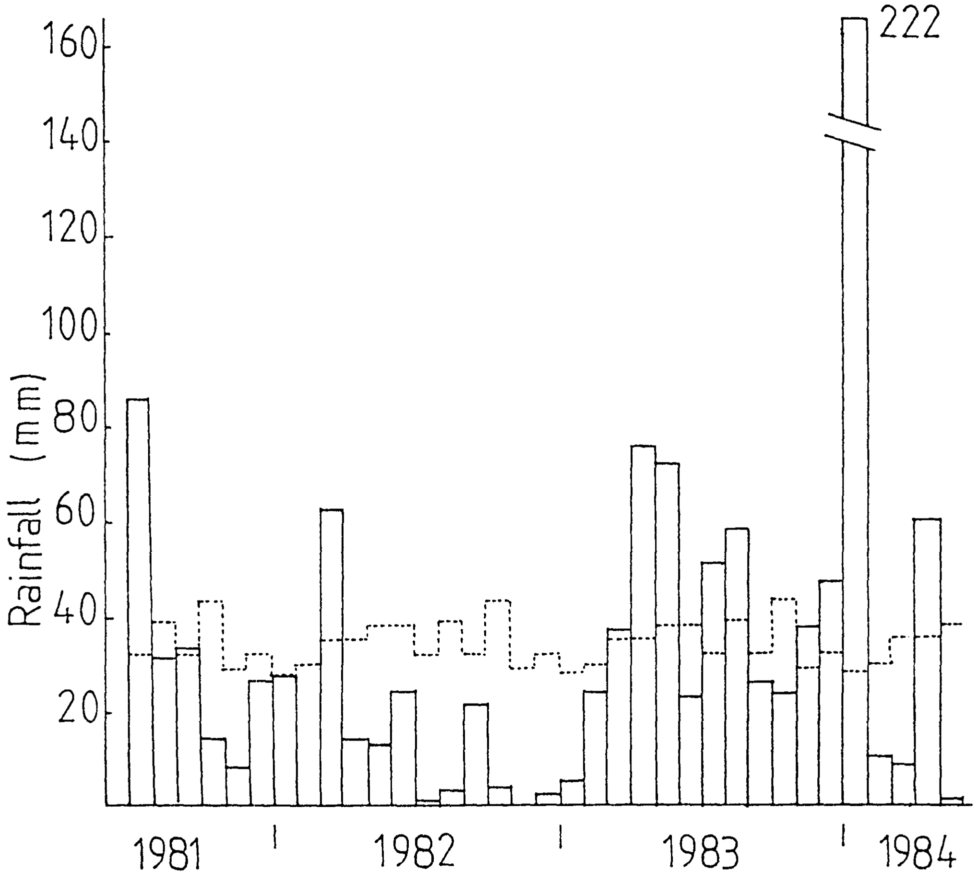
Rainfall recorded at Griffith for the period July 1981 - May 1984 is shown in Figure 6.1.

In 1982, a year of very low rainfall, 20 nests were found prepared for breeding (nests in a crater shape, full of leaf litter) but only five had any eggs laid in them. Many of the remaining 15 nests were not covered with sand, indicating that the litter within the mound was not wet enough to rot and produce heat for incubation (Frith 1959). There was a very wet winter in 1983 (Fig. 6.1) and 30 nests were found prepared. Of these, 26 later contained eggs. The remaining four were covered over and worked, but eggs were never found.

In 1983-84 the clutch at Mulyan was split between two nests and is shown on two lines in Table 6.1. The first six eggs were laid in a nest that was built in a rocky hole resulting from mining exploration. This nest had no drainage and when it became saturated (resulting in the soil and litter setting into a hard mass), the next five eggs were laid in the nest of the previous year. The leaf litter remaining in the 1982-83 nest was dampened by the heavy summer rains and produced sufficient heat for the incubation of eggs. The same colour-banded male attended both nests and, while it is not certain that the same female laid in both nests, it

Figure 6.1 Monthly rainfall at Griffith, July 1981 to May 1984
Mean annual total 411mm.

Dashed line shows mean monthly rainfall.



is highly probable as Malleefowl pair for life (Frith 1959).

6.3.2 Fate of eggs

Table 1 shows the fate of all eggs studied.

The fate of the eggs varied between the years of the study and differences were tested using Chi-square analysis. The number of infertile eggs varied significantly (X^2 = 13.7,5 d.f.,P <0.01) with a maximum of 30.8% infertile in the drought year 1982-83 and 11.7% in the wet year of 1983-84.

The exceptionally wet summer of 1983-84 resulted in the loss of 12.2% of the eggs; that year was the only one in which death of the embryos occurred when the egg chamber was saturated by heavy rainstorms, presumably preventing respiration (Seymour & Ackerman 1980).

Table 6.2 is a summary of the breeding data, and contains comparative data from Frith (1959). The percentage of eggs in each outcome is calculated as a percentage of eggs unaffected by human interference i.e. broken by observers, collected or vandalised.

There was no significant difference in the percentage of eggs from which chicks fledged successfully in the three years nor was there any significant difference in the percentage of eggs from which chicks hatched but were unable to leave the nest. There were also no

TABLE 6.1 Fate of 530 Malleefowl eggs laid 1981-1984

Nest	Laid	Unknown	Fox predation	Collected / vandalised	Broken by observer	Broken by Malleefowl	Infertile	Died in saturated nests	Laid too late	Other	Chick died in nest	Fledged
1981-82												
Pulletop 3	16	2				1	6		2	3		2
4	7									3		4
5	11					1			2	1	3	4
1982-83												
Mulyan 1	10						9				1	
Yalgogrin 13	3						2	1				
20	13	2	1			1	1				1	7
14	15	1	1				1		2			10
Arcadia 1	11						3					8
1983-84												
Yalgogrin 1	19	1										18
3	21	1	4	3			1	7	1			4
5	20										1	19
6	6		4					2				
7	15					2		1		1		11
8	15		2	6								7
9	15					2	2	5		1		5
10	19	1		5			1		2			10
12	10		1					3				6
13	19		3			5	4		1			6
14	10					1	1					8
16	15	1	1	8			1		3			1
17	12	1	1	7					2			1
19	5		5									
20	23						2		2			19
21	14			11	1		2					
* Mulyan 1st	6				1	2		3				
* 2nd	5								1			4
Arcadia 1	33	1			3	2	3	6	2		4	12
2	29				1	1	2	12	4			9
Buddigower 1	15		4		1			4			1	5
2	14				1		2	5				6
4	15	1			1	1		4		1	1	6
Pulletop 2	28				1		22				1	4
5	18						3					15
Loughnan 2	25							1		2		22
3	18	2						1	1		1	13
Total 1981-84	530	14	27	40	10	19	68	55	25	12	14	246
Percentage in each fate		2.6	5.1	7.5	1.9	3.6	12.8	10.4	4.7	2.3	2.6	46.4

* Data of one clutch laid in two nests.

TABLE 6.2 Summary of results of Malleefowl nests studied 1981-84 **with summary of data from Frith (1959).** Figures in parentheses are percentages of eggs in each fate excluding eggs affected by human interference.

	1981-82	1982-83	1983-84	All years 1981-84	Frith (1959)
Area searched	145 ha	908 ha	1812 ha		
Nests prepared	3	20	32	53	
Number of clutches	3	5	26	34	62
clutch size: mean	11.3	10.4	17.1	15.6	17.6
range	7-16	3-15	5-33	3-33	5-33
Mean date 1st egg	23Sept	28Oct	1 Oct	4 Oct	25Sept
Eggs laid	34	52	444	530	1094
Fate unknown	2(5.8)	3(5.7)	9(2.3)	14(2.9)	
Eggs lost					
taken by fox	0	2(3.8)	25(6.3)	27(5.6)	407(37.2)
collected or vandalised	0	0	40	40	
broken by observer	0	0	10	10	
broken by malleefowl	2(5.8)	1(1.9)	16(4.1)	19(4.0)	15(1.4)
Eggs remaining					
Infertile	6(17.6)	16(30.8)	46(11.7)	68(14.1)	
died in saturated nests	0	1(1.9)	54(13.7)	55(11.3)	86(7.9)
laid too late	4(11.8)	2(3.8)	19(4.8)	25(5.2)	14(1.3)
other failures	7(20.6)		5(1.3)	12(3.1)	30(2.7)
Hatchlings					
died in nest	3(8.8)	2(3.8)	9(2.3)	14(2.9)	
fledged	10(29.4)	25(48.1)	211(53.5)	246(51.3)	542(49.5)
Mean no. hatching:					
first 5 eggs	1.7	2.0	3.1	2.8	
last 5 eggs	1.3	1.8	1.9	1.8	

significant differences between years in the percentages of eggs laid too late to hatch before the nest was abandoned, or the percentage of eggs taken by foxes.

In 1983-84, 34 eggs (7.6% of eggs laid) disappeared without a trace from nests marked so they could be located from tracks in the area. When eggs disappeared all the eggs in the nest were taken. This pattern of egg loss suggests that they were taken by people, possibly collectors. Youths employed cutting broombush at Yalgogrin excavated a nest and smashed six eggs.

There were 24 clutches where the fate of the first and last five eggs laid could be compared. Clutches of less than 10 eggs, clutches that were partly collected and the clutch at Mulyan in 1983-84 were excluded. Chicks fledged from 60% of the first five eggs in a clutch, which was significantly greater (X^2 =8.8, $P < 0.005$, 1 d.f.) than the 40% that fledged from the last five eggs laid.

There were 135 eggs that failed to hatch due to infertility, saturated nests or other causes and, of these, 35 (25.9%) were in the first five eggs laid.

All eighteen chicks that hatched in incubators and survived the first few days were sexed: 14 were male and 4 were female D.Pridell (pers.comm.). This sex ratio is significantly different (X^2 = 5.56, $P<0.025$, 1 d.f.) from parity.

6.4 DISCUSSION

6.4.1 Differences between years, clutches and sites

In 1983-84, with exceptional rainfall, there was abundant growth of herbs throughout the mallee, in winter, spring and summer. Herbs are an important part of the Malleefowl diet (Frith 1962a) and so the abundance of this and other food can explain the large clutches in that year (Frith 1959).

There was a significant difference in the proportions of infertile eggs between years. Food shortages may cause infertility of eggs, as 30.8% were infertile in the drought year (1982-83) compared to 11.7% infertile in the wet year (1983-84). A possible explanation for clutches with many infertile eggs found at Pulletop is that it is a small reserve that has been isolated from other Malleefowl habitat for nearly 30 years and usually has only two breeding pairs of Malleefowl. One or both of a pair of breeding birds may be old infertile birds which have not been replaced by younger birds. This hypothesis cannot be tested as the ages of the infertile pair are unknown. However, another similar clutch with 19 of 22 eggs being infertile was laid at Pulletop in the 1984-85 breeding season (Brickhill, unpubl.).

The drought conditions of 1982-83 can explain why Malleefowl abandoned 15 nests prior to egg laying. Experiments have shown that even if there is sufficient moisture in the litter within the nest for production of heat, eggs will not be laid in drought conditions (Booth & Seymour 1984).

The differences in fledging rates between the first and last five eggs laid can be explained by the abnormal rainfall conditions in 1983-84. In that breeding season eggs were laid in February, which is unusually late (Frith 1959), and many did not hatch before nests were abandoned. More importantly, January 1984 had exceptionally heavy rainstorms with falls of over 100mm in 24h at Arcadia (N.Wheatley, pers.comm.). All of the nests in the area were saturated and almost all of the eggs in them failed to hatch.

The sex ratio of Malleefowl chicks (or adults) has not been reported previously. Further work is necessary to determine the sex ratio of chicks throughout the clutch before the importance of this phenomena can be determined.

6.4.2 Lack of eggs in "active" nests

The absence of eggs in four nests attended by male birds at Yalgogrin in 1983-84 is difficult to explain, and active nests without eggs have not been reported before this study. Conditions were suitable for many females to lay large clutches. The nests were not conspicuously marked as were the nests that had eggs collected from them, so it is unlikely that all these nests had all their eggs collected from them. One of the nests had a large cavity under the litter in the nest, which suggests an inexperienced nest builder (Frith 1962b, p.26).

Three of the four nests were maintained for three months from early November to mid-February, and the other was abandoned after one month. All four nests were abandoned before nests with eggs were abandoned (with the exception of nest 19, which had only 5 eggs laid in it, all of which were taken by foxes). It is possible that in 1983 in the Yalgogrin area of mallee there were insufficient females to pair with all males with nest mounds. The nests were not observed to see if females attended them. Some males may have maintained nests for several months in the hope of attracting a mate, and some sub-adult males may have built practice nests.

6.4.3 Comparison with other studies

The results of this study have been compared to those of Frith (1959) and Booth (1985). Frith's study site was at Pulletop, (one of my study sites) while Booth's study was near Renmark S.A., an area with a mean annual rainfall of only 264mm compared to 411mm at Griffith.

The mean clutch size was not significantly different in the three studies, being 13.8 eggs from 21 clutches, (Booth 1985), 15.6 from 34 clutches (this study) and 17.6 from 62 clutches studied (Frith 1959). The range was very similar in the three studies being 2-34, 3-33 and 5-33 respectively.

Booth (1985) found no fox predation of eggs, while in this study it accounted for 5.6% of eggs laid, and in Frith's study 37.2% of eggs were taken. In all the studies, fox scats were frequently found on the nest mounds throughout the breeding seasons, indicating that foxes frequently visited the mounds. Booth (1985) attributed his observed lack of fox predation to the large depth of loose sand covering the eggs in all nests which could not be penetrated by foxes. Certainly, casual observations in my study showed that smaller nests were more likely to have eggs taken by foxes than the larger higher nests.

Another difference between the three studies was that Frith (1959) did not have or did not recognise any infertile eggs, while in my study 14.1% of eggs were considered to be infertile, and in Booth's study 5.9% of eggs were infertile. There are no obvious explanations for differences in infertility rates between the studies.

The three studies found various proportions of eggs lost because of saturated nests, from none Booth (1985) to 7.9% Frith (1959) and 11.3% (this study). This cause of egg loss depends entirely on rare high rainfall events, and the high levels of losses found in my study would not be typical of the longer term situation.

Despite the differences in importance of fox predation and infertility between the study of Frith and the present study, the proportion of eggs hatched was not significantly different between the studies, with 49.5% hatching in the 1950's (Frith 1959) and 51.3% hatching in this study. Booth (1985) found 79.2% of eggs produced chicks, a much higher percentage than in both Frith's and my study in central N.S.W. This higher fledging rate was caused by a lack of fox predation and lack of wet weather effects (nest saturation). Thus, despite a lower clutch size, the number of chicks fledged per nest was 10.4 in Booth's study in the lower rainfall area, and 8.7 (Frith 1959) and 7.2 (this study) in a higher rainfall area.

All three studies have shown that Malleefowl have a high fecundity and this study has shown that an average of 7 chicks are leaving each nest each year.

As Malleefowl populations are in decline (Chapter 4) high mortality must be occurring at some later stage in the life cycle.