Chapter 7. DRINKING PATTERNS OF BIRDS OF THE PEERY STUDY AREA AND A DETAILED INVESTIGATION OF THE DRINKING BEHAVIOUR OF THE WHITE-PLUMED HONEYEATER.

Contents

7.1 Introduction

Early explorers of the arid zone fol owed birds to find water. They learned that certain birds, especially finches, pigeons and pari ots, were more reliable indicators of water than other birds (Kavanagh 1984). Charles Sturt welcomed '...the sight and sound of numerous diamond birds [Diamond Doves *Geopelia cuneata* , a sure sign of the proximity of water...', while John McDouall Stuart noted of Sturt Pla ns '...the absence of birds proclaims it to be destitute of water...'(Margery 1895 cited by Kavanagh 1984). In central and western arid Australia, Fisher *et al.* (1972) linked the drinking be iaviour of birds to their diets. Regular drinkers were predominantly granivorous species ind honeyeaters, while occasional or non-drinkers were largely invertebrate or vertebrate fe eders.

In arid New South Wale: , 'drought is the predominant characteristic' and is 'not merely an enemy to be occasionally encountered' (Anon 1901). Prior to European settlement, gilgais, clay pans, rock holes, creel s and desert lakes and playas provided only temporary water. More permanent water sources, such as wells maintained by Aborigines and natural artesian springs, were scarce (Kava iagh 1984). During prolonged droughts in arid New South Wales, birdlife would have been depauperate, as in all arid areas devoid of water, e.g. Ford & Sedgwick (1967), Davies (1969), Pianka & Pianka (1970), Serventy (1971), Wilson (1974), Maclean (1976). Today, European pastoral settlement encompasses arid New South Wales and stock watering points, mainly bores tapping underground water, occur at intervals of 5km or less. Overflow pools, troughs, tank; and drains associated with bores now provide permanent drinking water for birds in the area

In this chapter, I describe the use of water sources by birds within the Peery study area and investigate the drinking behaviour of the most abundant species, the White-plumed Honeyeater. In the concluding chapter of the thesis (Chapter 9), I discuss possible implications for birds of the provision of permanent water throughout arid New South Wales and discuss what might happen if bores were closed.

7.2 Study area and water sources

Chapter 2 provides a detailed descr ption of the study area. Throughout the study Peery Lake, which is adjacent to the study area, held water. Heavy rain in central Queensland in early 1990 flooded the Paroo River which filled Peery Lake with fresh water. The lake then progressively dried until December 1992, by whi h time its margin had receded 750 m from the study area. The lake was recharged by local fl(oding rain in January 1993. By the end of the study the lake margin had again receded ovei 500 m from the study area (Table 7.1).

Within the study area, a stock watering point, Kolstap Bore (Figure 7.1), provided permanent water. Kolstap Bore con prised an overflow pool fringed by Spiny Sedge *Cyperus gymnocaulos*, Boobialla *Myoporum montanum* shrubs and occasional Bimble Boxes *Eucalyptus populnea*, and three concrete stock troughs placed in the open.

Temporary water occurr d in holes in creeks. The location and permanence of creek waterholes varied as old hole silted up and new ones were scoured out by heavy rain. The most substantial held water for several weeks after rain and occurred within the lower reaches of Rutherfords Creek and Fox Creek (Figure 7.1). Depressions on the open plains and rock holes in the Peery Hills usuall / held water for only several days after rain. Dews were rare and none was noted during the drier portion of the study (spring 1990 - spring 1992 inclusive).

Cover available to drinking birds ranged from good at waterholes in creeklines to nil at the bore troughs, depressions on the open plains and along most of Peery Lake perimeter. The salinity of water in :reek waterholes was always low. Of 38 pools measured, the conductivity of only five exceeded 100 μS/cm and none exceeded 500 μS/cm. Water from Kolstap Bore was saline (range 11)00 - 13 000 μS/cm) and became very saline when concentrated by evaporation in stock troughs (up to 33 000 μS/cm). The salinity of water in Peery Lake increased as the Lake receded, with conductivity readings of up to 32 000 μS/cm recorded (Table 7.1).

Figure 7.1 **Sketch map of Peery study area indicating the location of water sources at which daylong watches were made.** Distance from Peery Lake edge was measured from the mid-point of the 'Bunny Beach' transect.
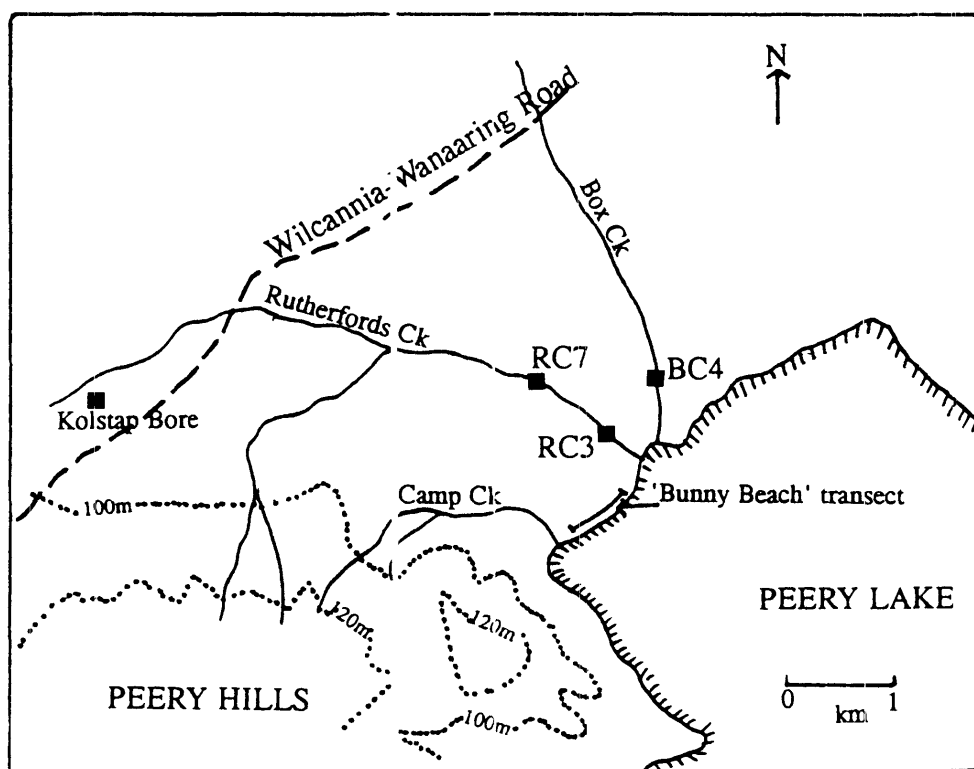
Table 7.1 **PEERY LAKE**. C)nductivity (salinity) of lake water and distance of lake edge from study area transect closest to the lake ('Bunny Beach')between October 1990 and January 1994.

Survey period	Distance from flood peak on Bunny Beach transect to lake edge (m)	Conductivity (μ S/cm)
(April 1990 flood)	0	
October 1990	25	1 000
July 1991	265	2 500
October 1991	315	3 400
July 1992	590	15 800
October 1992	750	32 000
(January 1993 flood)	80	
April 1993	325	3 000
July 1993	333	3 300
October 1993	364	4 500
January 1994	567	11 500

7.3 Methods

7.3.1 Use of water sources by bir ls in the Peery study area

I recorded all opportunistic observations of drinking birds in each census period. Dates of census periods were: 10 October - 7 November 1990; 2 - 23 July and 1 - 21 October 1991; 29 June - 23 July and 22 September - 8 October 1992; 9 - 22 April, 12 - 29 July and 28 September - 20 October 1993; 18 - 26 January 1994. For each drinking event I noted the species, size of drinking group, wa er source (lake, bore overflow pool, bore trough, creek waterhole, pool on plains or rock hole in Peery Hills), time of day and date. I measured salinity (conductivity) of water sou ces with a portable conductivity meter with a resolution of 100 μS/cm. Samples beyond the ra ige of the meter (19 900 μS/cm) were diluted with distilled water to allow measurement.

7.3.2 Drinking classification of all land birds in arid New South Wales

I classified all birds recorded in ari l New South Wales (area bounded by the 250mm median annual rainfall isohyet in the south ind the 350 mm isohyet in the north, Bureau of Meteorology 1988) since 1950 (Smith *et al.* 1994), apart from waterbirds, vagrants and introduced species, as regular drinkers (birds dependent on the presence of watering points), occasional drinkers (not obviously dependent on watering points but may drink occasionally) or non-drinkers. Classifications were based on published drinking records, unpublished observations of ornithologists familiar with birds of arid New South Wales (John Brickhill, Tony Douglas, Bill Flentje, Anne Creen, Graham Harrington, Glenn Holmes, Janet Houghton, John Izzard, Phil Maher, Nick Shepherd, Lola Smith, Peter Smith) and records from the Peery study area.

7.3.3 Systematic watches of drnk ing White-plumed Honeyeaters

Opportunistic observations of drinking White-plumed Honeyeaters were supplemented by

systematic watches made at Kolstap Bore, Peery Lake edge and waterholes in Rutherfords, Box and Camp Creeks. Nine continuous daylong watches, extending from 30 minutes before sunrise until dusk, were made in winter and spring 1992 (Table 7.2). Daylong watches were made from a hide erected several days prior to the watch to allow birds to become accustomed to it. Shorter watches, made from concealed positions, were made from various sites throughout the study and totaled 54 hours.

During systematic watches the number of White-plumed Honeyeaters and identity of marked individuals drinking in each 15-minute interval were recorded. Acts of aggression among drinking birds were noted. I recorded temperature at the start of each 15-minute interval, the conductivity of the water source and its distance from the closest alternative water. Cover for birds around the water source was assessed subjectively. Incidental observations of drinking birds of other species were also recorded during systematic watches.

Seven daylong watches were made at waterholes in Box and Rutherfords Creeks within White-plumed Honeyeater habitat, namely River Red Gum *Eucalyptus camaldulensis* and Black Box *E. largiflorens* woodland (Chapter 4). Two daylong watches were at Kolstap Bore, 150 m from eucalypt woodland. Colour bands were used to identify individual White-plumed Honeyeaters. Between spring 1991 and summer 1993/94 a total of 209 White-plumed Honeyeaters were captured in mist nets, banded and individually marked.

7.4 Results

7.4.1 Use of water sources by land birds at the Peery study site

Forty-two species of land birds were noted drinking at Peery (Table 7.3). Fourteen species were recorded drinking in spring, but not winter. These included the Rainbow Bee-eater. White-breasted Woodswallow and Budgerigar, which were absent from the site in winter. Six species were seen drinking only in winter. Of these the Little Friarbird and White-fronted Honeyeater were absent in spring and the Pink Cockatoo, a wide-ranging species, was recorded only rarely. The Southern Whiteface, Chestnut-crowned Babbler and Black-faced Cuckoo-shrike were, however, common and present in both seasons.

Table 7.2 **Details of system itic daylong watches.** At Kolstap Bore the overflow pool was watched continuously and the trough intermittently.

Watch no.	Date	Watch duration (hrs)	Location	Daily T range °C	Cover around waterpoint	Conductivity (μ S/cm)
1	6/7/92	11	RC3 waterhole	11-20	good	100
2	11/7/92	11	RC3 waterhole	1- 19	good	100
3	15/7/92	11	RC3 waterhole	3-24	good	100
4	19/7/92	11	BC3 waterhole	7-22	good	100
5	21/7/92	11	Kolstap Bore (overflow/trough)	4-18	mod/poor	11-1800
6	12/10/92	13	Kolstap Bore (overflow/trough)	14-27	mod/poor	12-2800
7	16/10/93	13.5	RC7 waterhole	13-17	good	100
8	17/10/93	13	RC7 waterhole	12-24	good	100
9	18/10/93	13	RC7 waterhole	16-23	good	100

Table 7.3 **Drinking patterns of land bird species in Peery study area**. Species drinking in Winter, Spring, Summer, or Autumn are indicated with +, species not present in study area in a given season are indicated with -. Conductivity refers to the conductivity of the most saline water drunk by each species. Drinking locations are **B** Kolstap Bore overflow pool, **L(n)** lake within 50m of cover, **L(o)** lake >50m from cover, **P** depressions on open plains, **R** rockhole, **T** stock trough at Kolstap Bore, **W** waterhole in creek. Status of each species is indicated as **R** resident **N** nomad **W** winter migrant or **S** spring-summer migrant.

	Status	Wi	Sp	Su	Au	Conductivity (μ S/cm)	Location
Emu	R	+	+	+		7 800	L(o),W
Peaceful Dove	N	+	+	-		100	W
Diamond Dove	N		+	+	+	11 500	L(n), L(o), T,W
Crested Pigeon	R	+	+	+	+	25 400	B,L(n),L(o),T,W
Galah	R	+	+	+	+	8 800	L(n), L(o), T,W
Little Corella	R		+	+	+	11 500	L(n), L(o),W
Pink Cockatoo	N	+				16 200	T.W
Budgerigar	N	-	+	-	+	200	L(n),W
Mallee Ringneck	R	+	+	+	+	25 400	B.W
Mulga Parrot	R	+	+			3 400	L(n),W
Blue Bonnet	R	+	+			15 800	B,L(n),L(o),R,W
Rainbow Bee-eater	S	-	+		-	3 400	L(o),W
Brown Treecreeper	R		+		+	200	W
Variegated Fairy-wren	R		+			11 100	B.W
Spiny-cheeked Honeyeater	R	+	+	+	+	14 300	B,L(n),T,W
Yellow-throated Miner	R	+	+	+	+	25 400	B,L(n),T,W
Little Friarbird	N	+	-	-	-	100	W
Singing Honeyeater	R	+	+	+		14 300]	B,T
Yellow-plumed Honeyeater	N	-	+	-	-	100	W
White-plumed Honeyeater	R	+	+	+	+	25 400	B,L(n),P,T,W
White-fronted Honeyeater	N	+	-	-	-	11 100	B
Crimson Chat	N		+			200	W
Orange Chat	N	-		+	-	25 400	L(o)
Striated Pardalote	R	+	+			11 100	B,W
Southern Whiteface	R	+				11 100	B
Red-capped Robin	W		+	-		100	W
Chestnut-crowned Babbler	R	+				200	W
Grey-shrike Thrush	R	+	+		+	100	W
Australian Magpie-lark	R	+	+	+		14 300	L(n),L(o),T,W
Willie Wagtail	R	+	+	+	+	11 100	L(n),W
Black-faced Cuckoo-shrike	R	+				200	W
White-breasted Woodswallow	R	-	+	+		11 500	L(o)
Australian Magpie	R		+	+		8 800	T,W
Australian Raven	R		+			3 400	L(o)
Little Crow	R		+	+		9 400	L(o),T
Apostlebird	R	+	+	+	+	9 300	B,L(n),T,W
Welcome Swallow	R		+	+		11 500	L(n),L(o)
Tree Martin	R	+	+	+		11 100	B,L(o),W
Rufous Songlark	N		+			100	W
Richard's Pipit	N		+			100	W
Mistletoebird	N		+	-		100	W
Zebra Finch	N	+	+	+	+	14 300	L(n),T,W

Birds used a variety of water sources, but most species (33 of the 42 species noted drinking) and most drinking bouts were recorded at waterholes in creeklines, which provided the best cover and water of lowest salinity (Table 7.3). Water drunk by birds ranged from fresh to highly saline. The Crested Pigeon, Mallee Ringneck, Yellow-throated Miner, White-plumed Honeyeater and Orange Chat drank water whose conductivity measured up to 25 400 μS/cm.

Daily drinking patterns of 16 species for which at least 10 drinking bouts were recorded overall are shown in Table 7.4. A number, including the White-plumed Honeyeater and Yellow-throated Miner, were recorded drinking in almost every half hour period of the day. Others, such as the Little Corella, Apostlebird and Australian Magpie-lark, were not recorded drinking during the middle of the day. Though data for a number of species in the table are inadequate to determine drinking patterns, the small number of species recorded drinking in the very early morning was notable. The period of the day with the fewest drinking records was 0600-0800, then 1200-1400. The period with the most drinking ecords was mid to late afternoon, 1500-1800. The scacity of drinking records for the 0600-0700 period is particularly noticeable.

7.4.2 Drinking classification of land birds of arid New South Wales

Since 1950, 165 species of birds, not including waterbirds, vagrants and introduced species, have been recorded in arid New South Wales (Smith & Smith 1994). On the basis of my observations and those of other ornithologists and records from the literature, 34% (56) of these birds can be classified as regular drinkers, 32% (52) as occasional drinkers and 35% (57) as non-drinkers (Appendix 7.1).

For the purpose of analysis two dietary categories, 'mixed plant foods' and 'mainly fruits', were combined so that cells had expected values which were not too low for the chi-squared test. The representation of dietary groups among the regular drinkers differed significantly from their representation among occasional or non-drinkers (chi-squared = 86.91, d.f. = 14, p < 0.01) (Table 7.5). Granivorous species, which include parrots, pigeons, doves and finches, tend to be regular drinkers as do honeyeaters whose diet comprises invertebrates

Figure 7.2 **Daily drinking patterns in Peery study area.** d indicates the 30 minute periods in which each species was recorded recorded drinking. **n** indicates the number of drinking bouts recorded for each species.

SPECIES	TIME (00HRS EST)												
	06	07	08	09	10	11	12	13	14	15	16	17	18
Emu (n=29)		d				d	d	d	d	d	d	d	
Diamond Dove (n=57)			d		d	d	d	d	d	d	d		
Crested Pigeon (n=31)		d	d	d	d	d	d	d	d	d	d	d	d
Galah (n=93)			d	d	d					d		d	d
Little Corella (n=472)				d	d	d	d	d	d	d	d	d	d
Budgerigar (n=49)		d	d	d	d	d		d		d	d	d	d
Mallee Ringneck (=13)			d	d	d	d	d	d		d	d	d	
Spiny-cheeked Honeyeater (n=87)			d	d	d	d	d	d	d	d	d	d	d
Yellow-throated Miner (n=554)		d	d	d		d	d	d	d		d	d	d
White-plumed Honeyeater (n=6111)		d	d	d	d	d	d	d	d	d	d	d	d
Australian Magpie-lark (n=153)	d	d	d	d	d	d	d		d	d	d	d	d
Willie Wagtail (n=24)				d	d			d			d		d
Apostlebird (n=386)			d	d	d	d	d	d	d	d	d	d	d
Tree Martin (n=64)		d	d	d	d	d	d	d	d	d	d	d	d
Rufous Songlark (n=18)				d					d	d	d	d	d
Zebra Finch (n=1017)			d	d	d	d	d	d	d	d	d	d	d
	06	07	08	09	10	11	12	13	14	15	16	17	18

Table 7.5 **Dietary characteristics of land birds of arid New South Wales in relation to the g oups of Regular, Occasional and Non drinkers.** Dietary classifications are derived from Smith & Smith (1994). Numbers in table are numb r of species.

DIET	Regular drinker	Occasional drinker	Non drinker	Total
Seeds	14	1	3	18
Invertebrates + seed or frui:	2	8	15	25
Invertebrates	8	22	22	52
Mainly vertebrates	0	6	11	17
Invertebrates + nectar/pollen/ plant exudates +/- fruit	19	5	1	25
Mixed plant foods	9	1	0	10
Invertebrates + some vertebrates	1	3	4	8
Omnivorous	1	5	1	7
Mainly fruits	2	1	0	3

and nectar/pollen/plant exudates. Species which feed predominantly on invertebrates or vertebrates, including carrion, tend to be occasional or non-drinkers.

Based on classifications in Appendix 7.1, the 95 land bird species recorded in the Peery study area (Chapter 3) comprised 35 regular, 36 occasional and 24 non-drinkers. Of the 71 regular or occasional drinkers at Peery, only 44 were actually seen drinking during the study. Known drinkers not seen drinking at Peery included rare and wide-ranging species which may have drunk unnoticed or outside the study area. On several occasions Spotted Nightjars hawked over waterholes after dusk on warm nights, but I was unable to determine if they were taking water or insects when they skimmed the water surface.

7.4.3 Drinking behaviour of the White-plumed Honeyeater

7.4.3.1 Incidence of drinking in White-plumed Honeyeater population

White-plumed Honeyeaters were observed drinking in all survey periods and all White-plumed Honeyeaters at the site appeared to drink. Of 59 White-plumed Honeyeaters colour-banded in winter 1992, all but one bird, which was never resighted, were recorded drinking. In summer 1993/94, 22 of 32 individuals colour-banded were noted drinking in a four hour watch at the water source closest to, but 1.1km distant from, the banding site. Drinking White-plumed Honeyeaters included adults in breeding (bill all black and gape black) and non-breeding (bill orange-yellow at base and gape yellow) phase, adults building nests, incubating, feeding nestlings and fledglings, independent juveniles (bill tip brown) and fledglings.

7.4.3.2 Daily drinking patterns of White-plumed Honeyeaters

White-plumed Honeyeaters drank throughout the day. In winter 1992, during three daylong watches at a waterhole in Rutherfords Creek (RC3), within White-plumed Honeyeater habitat and under fine, still conditions with no overnight dews, over 3 000 White-plumed Honeyeater drinking bouts were recorded. At this time the only alternative water sources in the study area were Kolstap Bore (6 km distant), Peery Lake (1 km distant) and waterhole BC4 (0.7 km

distant). Drinking frequency peaked in the late morning and was low at dawn and dusk (Figure 7.2). The number of White-plumed Honeyeater drinking bouts per hour was affected by the time of day (ANCOVA, d.f. = 10, p = 0.007), but was not related to temperature within the day.

A fourth daylong watch at a waterhole in Box Creek (BC4) in winter 1992 confirmed this daily drinking pattern. The three daylong watches in spring 1993 at Waterhole RC7, 400m upstream of Waterhole RC3, were undertaken when conditions were cool (temperatures ranged from 12-24 °C), windy, overnight dews were heavy, and it rained intermittently. White-plumed Honeyeaters drank throughout the day, but took water droplets from eucalypt leaves when available rather than coming down to the waterhole. Too few White-plumed Honeyeaters drank at Kolstap Bore, which was outside their preferred habitat, to discern any daily pattern during daylong watches there.

### 7.4.3.3 Daily drinking patterns of individual White-plumed Honeyeaters

Seventy-eight individually marked White-plumed Honeyeaters were observed drinking at Waterhole RC3 during the three daylong watches in winter 1992. Most individuals were observed drinking in four or fewer 5-minute periods of a given day and not all individuals were recorded drinking on each watch day. A small number drank much more frequently. with one individual recorded drinking in nineteen 15-minute intervals of a single day (Figure 7.3).

On a number of occasions during daylong watches large groups of colour-banded White-plumed Honeyeaters drank simultaneously. It was not possible for a single observer to record all colour combinations and the daily drinking frequency of some individuals would have been underestimated. However, when daylong watches were repeated at pools within a survey period, the number of daily drinking bouts recorded for each individual generally varied only slightly. Overall, individual differences remained marked. Individuals were consistently either frequent or infrequent drinkers at the waterhole. This appeared to be related to the distance of the waterhole from the bird's normal feeding site (Table 7.6).

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Figure 7.2 Total numbe of White-plumed Honeyeaters (WPHEs) drinking in each half hour of thre daylong watches at waterhole RC3 in winter 1992.

WPHES ——■—— Temperature
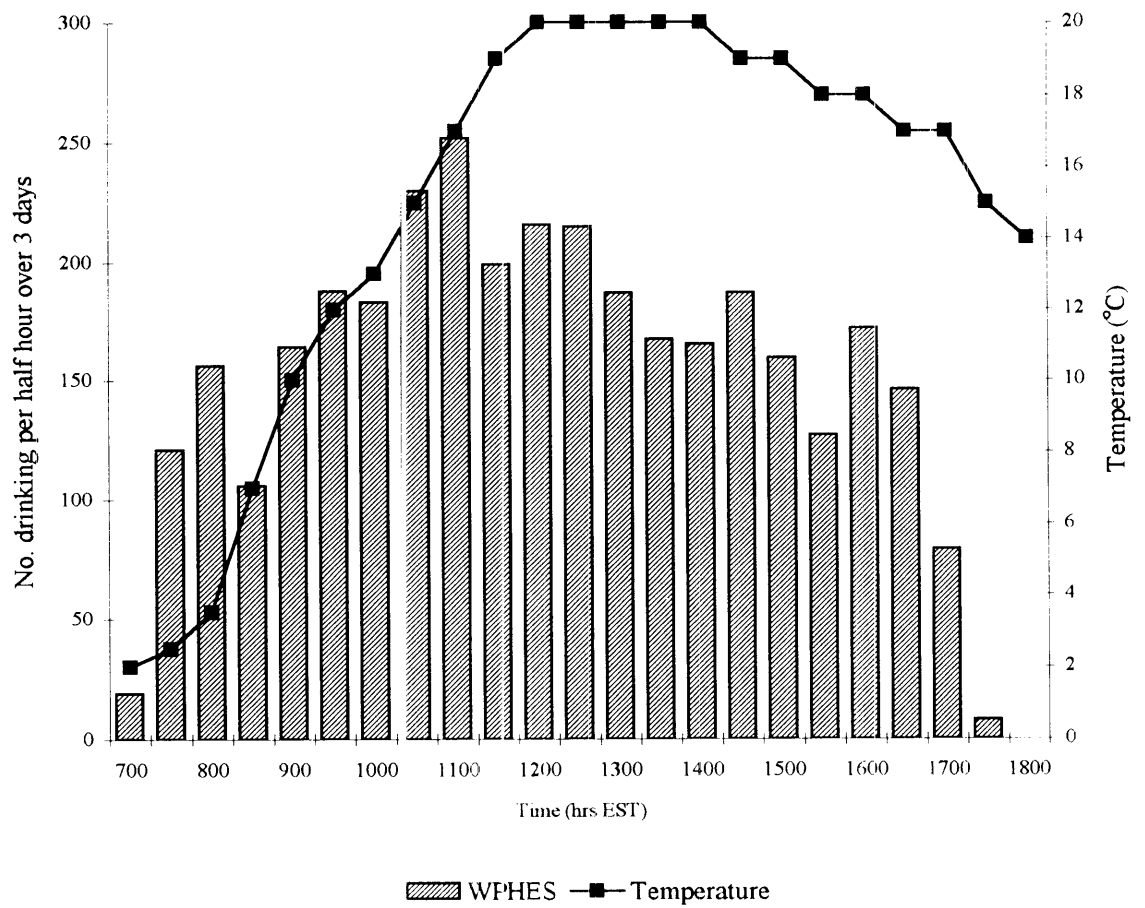
Figure 7.3 **Individual White-plumed Honeyeater daily drinking frequency at waterhole RC3 in winter 1992.**
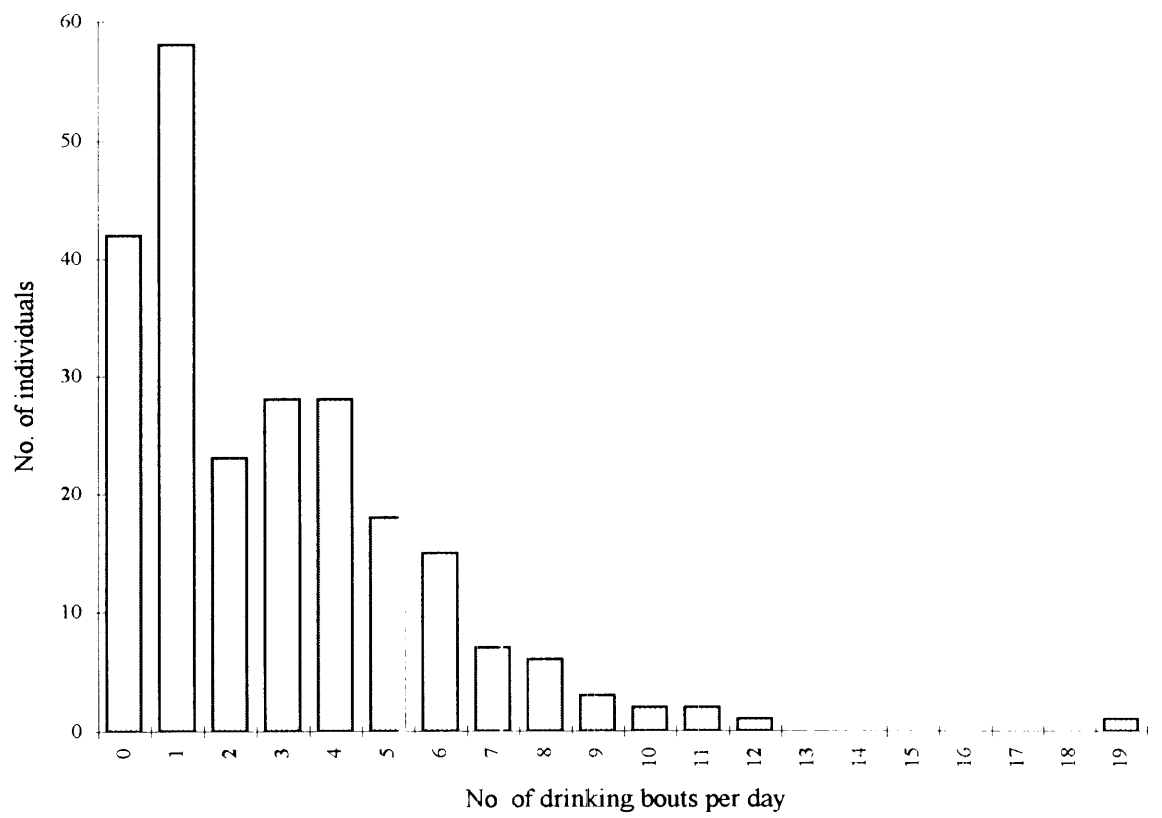
Table 7.6 **Drinking pattern;i of selected White-plumed Honeyeaters during three daylong watches at waterhole RC3 in winter 1992.**

The distance from feeding location was the distance measured along creekline habitat between waterhole RC3 and the section of creekline in which the individual was regularly observed feeding.

| Individual | No. of 15 min. periods drinking | | | Distance from |
	Day 1	Day 2	Day 3	feeding location (km)
P B/W	5	19	11	0
R O/Y	10	12	8	0
P P/W	4	3	2	0.7
P N/B	1	3	3	1.3
R Y/O	1	0	0	2.2
R B/B	0	0	1	6.0

7.4.3.4 Aggression among drinking White-plumed Honeyeaters

A small number of White-plumed Honeyeaters were aggressive towards other White-plumed Honeyeaters at drinking points. In creeklines, different individuals were aggressive at different waterholes. Aggressive individuals drank frequently throughout the day and were resident in the vicinity of the waterhole. Of the six individuals described in Table 7.6, for example, P B/W and R O/Y were aggressive, but the others were not.

7.4.3.5 Salinity of White-plumed Honeyeater drinking water

When available, White-plumed Honeyeaters drank water of low salinity in creekline waterholes. In summer 1993/94 all creekline waterholes in the study area were dry and then White-plumed Honeyeaters drank mainly from a couple of pools on the lakebed, 350m from the nearest eucalypt woodland. These pools, remnants of Peery Lake, were highly saline (25 400 μS/cm). These were the most heavily used water sources during the study, with up to 121 White-plumed Honeyeater drinking bouts recorded per 15-minute interval of a four hour watch at one of the pools. At this time White-plumed Honeyeaters also drank occasionally at the troughs and overflow (up to 15 000 μS/cm) at Kolstap Bore. This was the only summer survey and the high drinking frequency was probably related to the hot conditions.

7.5 Discussion

In arid New South Wales approximately one third of land birds require regular access to drinking water and a further third drink occasionally. The percentage of non-drinkers or occasional drinkers in arid New South Wales (67%) is similar to that estimated in arid central and western Australia (60%) by Fisher et al. (1972) and in the Namib desert of south-western Africa (70%) by Willoughby & Cade (1967).

   The distinction between regular and occasional drinkers was not always clearcut. The drinking frequency of species which are rare, wide-ranging or wary of people, may have been under-reported or unreported. Some species, for example the Australian Magpie, White-

breasted Woodswallow and Little C ow, were classified as occasional drinkers though they may drink frequently in hot weathe (pers. obs.) and, at such times, may be dependent on watering points. Laboratory studies have indicated that certain birds can survive for long periods without water e.g. Budgeri;ar (Cade & Dybas 1962) and Zebra Finch (Calder 1964, Cade et al. 1965). However, field cbservations suggest that these birds drink frequently in the wild and it is unclear whether findi igs mace in laboratory studies regarding water-dependency should be extrapolated to birds in tl e wild.

As in central and wester 1 arid Australia (Fisher et al. 1972), regular drinkers were predominantly granivorous species 25%) and honeyeaters (36%), while occasional drinkers or non-drinkers were predominantly ir vertebrate (69%) or vertebrate feeders (16%). Differences in drinking behaviour probably refl ct differences in quantities of pre-formed water in the diets of the various species. For granivorous species such as pigeons, doves, finches and parrots, dry surface seeds in arid environments may contain less than 10% moisture (Morton & MacMillen 1982). The only granivorous species which has been reported drinking only rarely is the Scarlet-chested Parrot (Pollar] 1965). Its apparent water-independence may be a consequence of its ability to locate and obtain water from succulent forbs such as pigweeds, purslanes and parakeelyas Caladrin a and Portulaca spp. (Forshaw & Cooper 1981). The high rates of drinking reported for hone]eaters may result from an accumulation of records from periods when they were taking few water-rich invertebrates. Their high levels of activity and pugnacious behaviour, which result in a relatively large amount of heat production, may also in part account for their need to dri ik (Fisher et al. 1972).

The diets of many arid zone species are opportunistic and generalised compared with birds of more mesic areas (Ch ipter 5). Presumably the water requirements of birds in arid areas vary as their diets change and as the water content of the same foods, e.g. seeds (Morton & MacMillen 1982) and h erbage, vary as conditions fluctuate. This may in part explain why several species never r ecorded drinking by Fisher et al (1972) drank at Peery. These included the Rufous Songlarl, which drank frequently in warm weather, and the Southern Whiteface, Variegated Fa ry-wren, Rainbow Bee-eater, Mistletoebird and White-breasted Woodswallow, which dran c rarely

Within the Peery study crea migratory species were occasional or non-drinkers.

Resident and nomadic species each included regular, occasional and non-drinkers. Fifty-four per cent of regular drinkers were residents and 46% were nomads, compared with 43% and 38% respectively for occasional/non-drinkers.

Birds drank close to where they were feeding if suitable water was available. Waterholes in creeks may have been preferred by many species because they coincided with their feeding areas. White-plumed Honeyeaters drank from depressions on the open plains only when they were close to (within 50 m) riparian eucalypt woodland. Waterholes in creeks provided cover and hence some protection from predators. However, birds were still exposed when drinking. On the few occasions when feral cats and foxes were seen approaching waterholes, birds stopped coming to drink. During systematic watches in Rutherfords Creek few White-plumed Honeyeaters ventured down to pools when Collared Sparrowhawks were near. The only birds observed drinking from the exposed margin of Peery Lake were aerial feeders, which skimmed the water surface and may have been relatively safe from predators, and large ground-feeding birds which fed widely on the open plains. The Emu, Galah and Little Corella were the only birds regularly observed drinking at the lake margin. Blue Bonnets drank from small rock holes in the Peery Hills as they gleaned seed caught between rocks. Blue Bonnets drank in small groups and Galahs and Little Corellas in flocks of up to several hundred birds. Possibly their flocking behaviour enabled them to detect and avoid predators more efficiently than single birds or smaller groups of birds, and hence allowed them to drink in exposed situations. They are also relatively large, and so have fewer predators than smaller birds.

Birds can distinguish between salt concentrations and avoid more saline solutions when possible (Bartholomew & Cade 1963, Willoughby 1971, Williams & Main 1977). Waterholes in creeks may have been preferred by many species because they provided the least saline water. Creek pools in central and western arid Australia usually remain potable for at least six months, and possibly longer, after rainfall (Fisher et al. 1972). Galahs and Little Corellas showed a preference for water of low salinity when they congregated at Kolstap Bore to feed on the fruits of *Atriplex spongiosa*. During lengthy feeding sessions the birds flew off at roughly hourly intervals to drink at a waterhole approximately 200 m distant in Rutherfords Creek and then returned to the Bore to resume feeding. They ignored the considerably closer,

but more saline, water in the bore troughs and overflow pool. When fresh water was unavailable a number of species, including the Crested Pigeon, Yellow-throated Miner, White-plumed Honeyeater and Orange Cha , drank water even more saline than that tolerated by sheep (Jacobson *et al.* 1983). Though birds drank this water, it is unlikely that many species could survive for long under field conditions if restricted to such saline drinking water (Williams & Main 1977).

Fisher *et al.* (1972) obtained data over a wide temperature range at every season of the year. They concluded that different arid zone species have characteristic times of day when drinking occurs, which may be related to avoidance of high daytime temperatures. However, a number of species in their study, including the Tree Martin, Apostlebird. Australian Raven, Little Crow and Emu, drank throughout the day, but slightly more frequently in the middle of the day. Possibly the Tree Martin and Apostlebird were collecting mud for nests rather than, or as well as, drinking. Results of 40 hours of continuous observation at five waterholes in arid Western Australia indicated that most species drank at dawn and dusk as well as, but to a lesser extent than, during the day. Evans *et al.* (1985) discerned differences in the daily drinking patterns of seven estrilidine finches in north-western Australia, which they related to predator avoidance. The Budgerigar (Wyndham 1980) and Diamond Dove (Schleucher 1993), however, do not appear to drink at specific times of day. The relative lack of drinking activity at Peery in the early morning may have been a consequence of the cold conditions under which many watches were made. Similarly avoidance of drinking in the hot midday period may have been masked by the number of observations made when midday temperatures were mild. Davies (1972) found that the Yellow-throated Miner, a common arid zone species, drank only in the morning, but in this study and that of Fisher *et al.* (1972) it drank throughout the day.

The White-plumed Honeyeater, which is usually associated with riverine eucalypt woodland (Chapter 4), was the most frequently recorded drinking species at Peery. Records of occasional individuals and small parties in eucalypts well away from watercourses have led to the claim that they have the ability to survive without access to surface water (Blakers *et al.* 1984). At Peery, when water was scarce, individually marked White-plumed Honeyeaters regularly travelled up to 6 km from their feeding sites to drink. Only in arid areas not settled by pastoralists does water occur at intervals of more than 5 km. It is likely that White-plumed

Honeyeaters found some distance from water are still drinking regularly. As well as taking ground water, White-plumed Honeyeaters are able to hang head-down in foliage and suck up dew and rain drops from hanging leaf tips. On rainy days at Peery they preferred to take water from foliage rather than come down to ground level waterholes.

Individual White-plumed Honeyeaters varied considerably in the frequency at which they drank and this appeared to be related to the distance between their watering and feeding sites. Individuals may need to balance a benefit obtained from drinking frequently with the energetic cost of travelling to water. Some individuals may be using more than one watering point. The very high drinking frequencies of individuals resident within the vicinity of a pool suggested that, for these birds, the reed to drink was social as well as physiological. Birds resident about pools were recorded drinking in up to nineteen 15-minute intervals of a day, and often drank several times within a 15-minute interval. It is unlikely that they needed all the water they drank to maintain water balance. There seems little point to defending a water source when the loss of water due to evaporation would far exceed the amount drunk. However, the frequent drinking bouts of resident White-plumed Honeyeaters may have been related to a need to assert their dominance over influxes of visiting drinkers into their territory. White-plumed Honeyeaters were aggressive towards other White-plumed Honeyeaters only at the pool at which they were resident. The highly aggressive individual P B/W in Table 7.6, for example, showed no aggression when forced by water availability to drink at a water source 900m from its own pool in summer 1993/94. No acts of aggression by White-plumed Honeyeaters were noted at this particular waterhole, presumably because it was not within any individual's territory. Further banding studies are needed to determine if individuals of species, in addition to the White-plumed Honeyeater, vary in their daily drinking frequency.

I was unable to demonstrate a correlation between drinking frequency and temperature under mild conditions. However, my limited observations at high temperatures ($> 40 \, ^{\circ}C$) in January 1994 supported the conclusion of Fisher et al. (1972) that temperature exerts a major influence on drinking frequency. Water is needed to replace evaporative water loss and to aid thermoregulation. Possibly the relationship between temperature and drinking ffrequency is complex. There may be a low threshold temperature at which drinking commences and a higher threshold at which all activity declines.

The frequency of drinking bouts at a water point was in part dependent on the availability of alternative water and hence the area from which drinking birds were drawn. Factors such as this and temperature water quality, the location of water in relation of cover and the frequency at which individuals drink, need to be considered when counts of drinking birds are used as measures of population density.

The study at Peery encompassed a severe drought and populations of resident birds declined (Chapter 3). Notably, the only residents whose populations increased were the Grey Shrike-thrush, an occasional drinker which is probably water-dependent in hot weather, and the White-plumed Honeyeater, a regular drinker throughout the year. At Peery, and throughout arid New South Wales, the provision of reliable water at regular intervals by pastoralists has extended the permanent range of many, if not all, species that are dependent on drinking water, either year round or during hotter periods. At Peery, the White-plumed Honeyeater concentrated in riparian eucalypt woodland (Chapter 4), the richest and most stable habitat of the area. It is a highly aggressive species (Chapter 8). Artificial water supplies enable it to persist in sites that were once waterless during extended droughts. During droughts it may now exclude small birds, including water-independent species adapted to endure droughts, from what is most likely a drought refuge The long-term effects of increased competition from water-dependent species during drought on water-independent species are unknown but likely to be highly detrimental.

Appendix 7.1. **Drinking classification of land birds (excluding vagrants and introduced species) recorded in arid NSW since 1950.** Nomenclature follows Simpson & Day 1993

REGULAR DRINKERS:	OCCASIONAL DRINKERS:	NON-DRINKERS:
Emu *Dromaius novaehollandiae*	Black Kite *Milvus migrans*	Black-shouldered Kite *Elanus notatus*
Australian Pratincole *Stiltia isabella*	Brown Goshawk *Accipiter fasciatus*	Square-tailed Kite *Lophoictinia isura*
Flock Bronzewing *Phaps histrionica*	Collared Sparrowhawk *Accipiter cirrhocephalus*	Black-breasted Buzzard *Hamirostra melanosternum*
Common Bronzewing *Phaps chalcoptera*	Little Eagle *Hieraaetus morphnoides*	Spotted Harrier *Circus assimilis*
Squatter Pigeon *Geophaps scripta*	Wedge-tailed Eagle *Aquila audax*	Grey Falcon *Falco hypoleucos*
Crested Pigeon *Geophaps lophotes*	Brown Falcon *Falco berigora*	Australian Kestrel *Falco cenchroides*
Diamond Dove *Geopelia cuneata*	Malleefowl *Leipoa ocellata*	Australian Hobby *Falco longipennis*
Peaceful Dove *Geopelia placida*	Bush Thick-knee *Burhinus grallarius*	Peregrine Falcon *Falco peregrinus*
Red-tailed Black Cockatoo *Calyptorhynchus banksii*	Banded Lapwing *Vanellus tricolor*	Black Falcon *Falco subniger*
Cockatiel *Leptolophus hollandicus*	Inland Dotterel *Peltohyas australis*	Stubble Quail *Coturnix pectoralis*
Pink Cockatoo *Cacatua leadbeateri*	Scarlet-chested Parrot *Neophema splendida*	Little Button-quail *Turnix velox*
Sulphur-crested Cockatoo *Cacatua galerita*	Horsfield's Bronze-cuckoo *Chrysococcyx basalis*	Red-chested Button-quail *Turnix pyrrhothorax*
Little Corella *Cacatua pastinator*	Spotted Nightjar *Caprimulgus argus*	Kori Bustard *Ardeotis kori*
Galah *Cacatua roseicapilla*	Fork-tailed Swift *Apus pacificus*	Plains Wanderer *Pedionomus torquatus*
Red-winged Parrot *Aprosmictus erythropterus*	Sacred Kingfisher *Todiramphus sanctus*	Masked Lapwing *Vanellus miles*
Regent Parrot *Polytelis anthopeplus*	Rainbow Bee-eater *Merops ornatus*	Pallid Cuckoo *Cuculus pallidus*
Budgerigar *Melopsittacus undulatus*	White-backed Swallow *Cheramoeca leucosternum*	Fan-tailed Cuckoo *Cacomantis flabelliformis*
Mallee Ringneck *Barnardius zonarius*	Fairy Martin *Hirundo ariel*	Black-eared Cuckoo *Chrysococcyx osculans*
Mulga Parrot *Psephotus varius*	Richard's Pipit *Anthus novaeseelandiae*	Southern Boobook *Ninox boobook*
Red-rumped Parrot *Psephotus haematonotus*	Black-faced Cuckoo-shrike *Coracina novaehollandiae*	Barking Owl *Ninox connivens*
Blue Bonnet *Northiella haematogaster*	White-winged Triller *Lalage tricolor*	Barn Owl *Tyto alba*
Blue-winged Parrot *Neophema chrysostoma*	Red-capped Robin *Petroica goodenovii*	Tawny Frogmouth *Podargus strigoides*
Bourke's Parrot *Neophema bourkii*	Hooded Robin *Melanodryas cucullata*	Australian Owlet-nightjar *Aegotheles cristatus*
Welcome Swallow *Hirundo neoxena*	Jacky Winter *Microeca leucophaea*	Laughing Kookaburra *Dacelo novaeguineae*
Tree Martin *Hirundo nigricans*	Rufous Whistler *Pachycephala rufiventris*	Red-backed Kingfisher *Todiramphus pyrropygius*
Willie Wagtail *Rhipidura leucophrys*	Gilbert's Whistler *Pachycephala inornata*	Dollarbird *Eurystomus orientalis*
Red Wattlebird *Anthochaera carunculata*	Grey Shrike-thrush *Colluricincla harmonica*	Singing Bushlark *Mirafra javanica*
Striped Honeyeater *Plectorhyncha lanceolata*	Restless Flycatcher *Myiagra inquieta*	Ground Cuckoo-shrike *Coracina maxima*
Spiny-cheeked Honeyeater *Acanthagenys rufogularis*	Grey-crowned Babbler *Pomatostomus temporalis*	Southern Scrub-robin *Drymodes brunneopygia*
Noisy Friarbird *Philemon corniculatus*	White-browed Woodswallow *Pomatostomus superciliosus*	Crested Shrike-tit *Falcunculus frontatus*
Little Friarbird *Philemon citreogularis*	Chestnut-crowned Babbler *Pomatostomus castaneothorax*	Red-lored Whistler *Pachycephala rufogularis*
Blue-faced Honeyeater *Entomyzon cyanotis*	Rufous Songlark *Cinclorhamphus mathewsi*	Golden Whistler *Pachycephala pectoralis*
Yellow-throated Miner *Manorina flavigula flavigula*	Splendid Fairy-wren *Malurus splendens*	Crested Bellbird *Oreoica gutturalis*
Black-eared Miner *Manorina flavigula melanotis*	Variegated Fairy-wren *Malurus lamberti*	Chirruping Wedgebill *Psophodes cristatus*
Noisy Miner *Manorina melanocephala*	Weebill *Smicrornis brevirostris*	Grey Fantail *Rhipidura fuliginosa*
Singing Honeyeater *Lichenostomus virescens*	Chestnut-rumped Thornbill *Acanthiza uropygialis*	Chestnut Quail-thrush *Cinclosoma castanotum*
White-eared Honeyeater *Lichenostomus leucotis*	Southern Whiteface *Aphelocephala leucopsis*	Cinnamon Quail-thrush *Cinclosoma cinnamomeum*
Yellow-plumed Honeyeater *Lichenostomus ornatus*	Brown Treecreeper *Climacteris picumnus*	Chestnut-breasted Quail-thrush *Cinclosoma castaneothorax*
Grey-fronted Honeyeater *Lichenostomus plumulus*	Gibberbird *Ashbyia lovensis*	Halls Babbler *Pomatostomus halli*
White-plumed Honeyeater *Lichenostomus penicillatus*	Mistletoebird *Dicaeum hirundinaceum*	Brown Songlark *Cinclorhamphus cruralis*
Brown-headed Honeyeater *Melithreptus brevirostris*	Striated Pardalote *Pardalotus striatus*	White-winged Fairy-wren *Malurus leucopterus*
Brown Honeyeater *Lichmera indistincta*	Black-faced Woodswallow *Artamus cinereus*	Grey Grasswren *Amytornis barbatus*
Painted Honeyeater *Grantiella picta*	Masked Woodswallow *Artamus personatus*	Striated Grasswren *Amytornis striatus*
White-fronted Honeyeater *Phylidonyris albifrons*	White-browed Woodswallow *Artamus superciliosus*	Thick-billed Grasswren *Amytornis textilis*
Black Honeyeater *Certhionyx niger*	White-breasted Woodswallow *Artamus leucorhynchus*	Shy Hylacola *Sericornis cautus*
Pied Honeyeater *Certhionyx variegatus*	Dusky Woodswallow *Artamus cyanopterus*	Redthroat *Sericornis brunneus*
Crimson Chat *Epthianura tricolor*	Pied Butcherbird *Cracticus nigrogularis*	Rufous Calamanthus *Sericornis campestris*
Orange Chat *Epthianura aurifrons*	Australian Magpie *Gymnorhina tibicen*	Western Gerygone *Gerygone fusca*
White-fronted Chat *Epthianura albifrons*	Pied Currawong *Strepera graculina*	Brown Thornbill *Acanthiza pusilla*
Zebra Finch *Taeniopygia guttata*	Australian Raven *Corvus coronoides*	Yellow-rumped Thornbill *Acanthiza chrysorrhoa*
Double-barred Finch *Taeniopygia bichenovii*	Little Raven *Corvus mellori*	Yellow Thornbill *Acanthiza nana*
Spotted Bowerbird *Chlamydera maculata*	Little Crow *Corvus bennetti*	Banded Whiteface *Aphelocephala nigricincta*
White-winged Chough *Corcorax melanorhamphos*		Orange-winged Sittella *Daphoenositta chrysoptera*
Apostlebird *Struthidea cinerea*		White-browed Treecreeper *Climacteris affinis*
Australian Magpie-lark *Grallina cyanoleuca*		Red-browed Pardalote *Pardalotus rubricatus*
Grey Butcherbird *Cracticus torquatus*		Little Woodswallow *Artamus minor*
		Olive-backed Oriole *Oriolus sagittatus*

Chapter 8. PATTERNS OF AGGRESSION

Contents

8.1 Introduction

Davies (1982) concluded that aggression in arid zone birds was rare. He proposed that this apparent lack of aggression was a social adaptation to an environment in which birds needed to avoid excessive heat production and minimise water loss. This proposition assumes that a lack of aggression is characteristic of all arid zone species, but aggression in Australian arid zone birds has not been studied at a community level.

Many common arid zone species feed in flocks. At Peery, 29 of the 44 species whose foraging behaviour was analysed quantitatively generally fed in single or mixed species flocks (Chapter 5). Aggression has been found to be rare in arid zone species which form feeding flocks, including babblers (Balda & Brown 1977, King 1980), Budgerigars (Wyndham 1980) and Pink Cockatoos (Rowley & Chapman 1991) in Australia, and sandgrouse *Pterocles* spp. (Thomas *et al.* 1981) in Africa. A lack of aggression has also been noted in arid zone birds congregating in cooler refuges during periods of intense heat. Such groups include a range of common arid zone species such as Zebra Finch, Budgerigar, Crimson Chat, Australian Magpie-lark, Willie Wagtail and Rainbow Bee-eater (Finlayson 1932) and Splendid *Malurus splendens* and White-winged Fairy-wrens (Ambrose 1984). A consistent lack of aggression has not, however, been confirmed in arid zone honeyeaters (family Meliphagidae),

which, in more mesic environments, are renowned for their aggressive behaviour (e.g. Dow 1977, Ford & Paton 1982, Loyn *et al.* 1983, Woinarski 1984, McFarland 1985, Chan 1990, 1995, Davis & Recher 1993, Ford & Debus 1994). Honeyeaters such as the Bell Miner *Manorina melanophrys* (Smith & Robertson 1978, Poiani *et al.* 1990, Poiani 1991), Red Wattlebird *Anthochaera carunculata* and Noisy Friarbird *Philemon corniculatus* (Ford & Debus 1994) are aggressive to many species, but their targets are usually potential competitors and nest predators, while the Noisy Miner *M. melanocephala* (Dow 1977) is apparently indiscriminately aggressive to other birds.

In this chapter I describe the incidence of aggressive behaviour within the Peery bird community. I compare levels of aggression between species and between the different movement status groups (residents, nomads and migrants). I ask whether such aggression that does occur is indiscriminate or is directed at particular species or feeding groups. Finally, I consider the role of aggression in this community.

8.2 Methods

The study was undertaken between spring 1990 and summer 1993/94. Birds at the site were censused on nine occasions (Chapter 3). A total of 97 land bird species was recorded, of which 81 were recorded in censuses. These 81 species comprised 42 residents, 28 nomads, six spring-summer migrants and five winter migrants. A detailed description of the study site is given in Chapter 2.

Aggression at the study site took various forms, including 'chasing', where a bird flies at another and forces it to leave the area, and 'arcing', where a bird hovers back and forth about an intruder, behaviours described by McFarland (1984). Aggressive behaviours were often accompanied by loud calling and occasionally involved actual physical contact. I did not include incidences of pursuit, whose object was predation, as a form of aggression.

Observations of intra- and inter-specific aggression were made opportunistically in each survey period while censusing and collecting other data. For each instance of aggression I recorded the species and number of individuals perpetrating the aggression and those at which the aggression was directed. I noted the presence of nearby nests and drinking pools.

For the purpose of analysis I counted each aggressive event, whether it involved one or several birds acting as a group, as a single act of aggression for the aggressor and target species concerned. I summed observations of all forms of aggression for each species. For the 81 species recorded in censuses I compared the number of acts of aggression observed with the number expected, considering the varying abundances of different species, if all species are equally aggressive. I calculated the number expected for each species as the product of the total number of aggressive acts recorded in all species recorded in censuses and the relative density of that species. Relative densities were derived from results of all censuses. For species sufficiently common that the expected value was greater than five, I used *chi*-square analyses, incorporating Yates' Correction for Continuity, to test if that species was significantly more or less aggressive than expected. Similarly, I compared the number of acts of aggression directed towards each species with that expected, if all species are equally the target of aggression. As I was not always able to distinguish Little Crows and Australian Ravens, I combined results for these two species. *Chi*-square analysis was also used to test the significance of differences between residents, nomads and migrants in levels of aggressive activity.

8.3 Results

A total of 462 aggressive acts perpetrated by 33 species was recorded. This aggression was directed at 56 species (Appendix 8.). Overall, residents and migrants were significantly more aggressive than nomads (*chi*-square I = 28.03, d.f. = 2, p < 0.01) (Table 8.1). Differences between residents, nomads and migrants, in terms of how frequently they were the targets of aggression, were not significant (p > 0.05).

Seventeen residents and wo nomads were sufficiently numerous that the number of aggressive acts performed by them and directed towards them was expected to be greater than five. Of these 19, four species were significantly more aggressive and 13 (including the two nomads) significantly less aggressive than expected (Table 8.2).

Significantly more aggressive species were the Yellow-throated Miner and White-plumed Honeyeater (family Meliphagidae), and the Willie Wagtail and Australian Magpie-lark (family Monarchidae). Each of these was aggressive towards a number of other species: the

Table 8.1 **Comparison of levels of aggression in residents, nomads and migrants.**

Numbers in table are percentages and indicate the relative frequency of aggressive incidents initiated by and directed towards residents, nomads and migrants. The relative abundance of each movement group is derived from results of all censuses (Chapter 3).

	Residents	Nomads	Migrants
Aggressor (n=462)	93	3	4
Target (n=462)	82	12	6
Relative abundance	82	16	2

Table 8.2 **Comparison of the frequencies with which species behaved aggressively or were the targets of aggression with that observed overall**. Species included in the table are those for which the expected number (EXP) of acts of aggression performed by them and directed towards them is greater than five. Results of chi-square analyses (d.f. = 1) to test for differences between the number observed (**OBS**) and number expected are given. Levels of significance are *<0.05 **<0.01 ***<0.001. Significant differences were found where the number observed was **more** or **less** than expected. Status is indicated as **R** resident or **N** nomad.

SPECIES	STATUS	EXP.	AGGRESSOR OBS.	χ^2	sig.		TARGET SPECIES OBS.	χ^2	sig.	
Crested Pigeon	R	8.58	0	7.73	**	less	3	3.04	n.s	
Galah	R	7.78	0	6.94	**	less	6	0.22	n.s.	
Budgerigar	N	32.12	0	33.44	***	less	2	29.34	***	less
Mallee Ringneck	R	7.86	0	7.01	**	less	6	0.24	n.s.	
Blue Bonnet	R	8.63	1	6.01	*	less	3	3.11	n.s.	
Brown Treecreeper	R	6.47	0	5.58	*	less	4	0.60	n.s.	
Variegated Fairy-wren	R	10.57	1	7.95	**	less	6	1.59	n.s.	
White-winged Fairy-wren	R	7.82	1	5.20	*	less	1	5.20	*	less
Spiny-cheeked Honeyeater	R	12.43	12	0	n.s.		20	4.12	*	more
Yellow-throated Miner	R	25.74	79	114.35	***	more	52	27.24	***	more
White-plumed Honeyeater	R	99.21	219	182.68	***	more	52	28.00	***	less
Chestnut-rumped Thornbill	R	5.91	2	1.99	n.s.		3	0.99	n.s.	
Southern Whiteface	R	7.52	0	6.67	**	less	0	6.67	**	less
Chestnut-crowned Babbler	R	11.46	3	5.69	*	less	8	0.79	n.s.	
Australian Magpie-lark	R	5.35	25	69.32	***	more	14	12.55	***	more
Willie Wagtail	R	17.54	42	34.06	***	more	41	31.28	***	more
Apostlebird	R	24.68	6	14.16	***	less	14	4.44	*	less
Tree Martin	R	70.67	3	75.38	***	less	2	77.64	***	less
Zebra Finch	N	34.83	0	36.61	***	less	10	18.39	**	less

White-plumed Honeyeater (36 species), the Yellow-throated Miner (27), the Willie Wagtail (15) and the Australian Magpie-lark (13). Seventy-nine per cent of species targeted by the Willie Wagtail were larger than it, compared with 72% for the White-plumed Honeyeater, 54% for the Australian Magpie-lark and 48% for the Yellow-throated Miner. These birds did not selectively attack other birds which foraged on similar substrates (Table 8.3). Only 31% of species and 34% of individuals targeted by the White-plumed Honeyeater showed any potential for dietary overlap (Chapter 5) compared with 31% and 36% for the Australian Magpie-lark, 33% and 29% for the Yellow-throated Miner, and 50% and 21% for the Willie Wagtail. Intraspecific aggression accounted for 8% of aggression recorded in the Australian Magpie-lark, 14% in the Yellow-throated Miner, 18% in the White-plumed Honeyeater and 21% in the Willie Wagtail. Several species for which data were insufficient to perform chi-square analyses, including the resident Australian Magpie and Australian Raven/Little Crow, and migratory White-winged Triller, also appeared to be unusually aggressive. All aggressive acts recorded for the White-winged Triller involved males in breeding plumage and 50% were intraspecific.

The 13 species significantly less aggressive than expected were drawn from nine families: Columbidae (Crested Pigeon), Psittacidae (Galah, Budgerigar, Mallee Ringneck and Blue Bonnet), Climacteridae (Brown Treecreeper), Maluridae (Variegated and White-winged Fairy-wren), Pardalotidae (Southern Whiteface), Pomatostomidae (Chestnut-crowned Babbler), Corcoracidae (Apostlebird), Hirundinidae (Tree Martin) and Passeridae (Zebra Finch). These were largely seed-eaters or insectivores and all but the Brown Treecreeper and Mallee Ringneck fed in single or mixed-species flocks (Chapter 5).

Of the 19 species included in the analysis, the Willie Wagtail, Australian Magpie-lark, Spiny-cheeked Honeyeater, and Yellow-throated Miner were significantly more often the target of aggression than expected. Most aggression directed towards the Yellow-throated Miner and Willie Wagtail came from the White-plumed Honeyeater and towards the Australian Magpie-lark and Spiny-cheeked Honeyeater from the White-plumed Honeyeater and Yellow-throated Miner. Six species, including the White-plumed Honeyeater, the most aggressive bird in the study area, were targeted significantly less often than expected. Others were the Budgerigar, White-winged Fairy-wren, Southern Whiteface, Apostlebird, Tree Martin and

Table 8.3 Proportion of attacks directed towards each feeding group identified in Chapter 5 by four significant y aggressive species. Figures in table are percentages.

AGGRESSOR	FEEDIN(; GROUP OF AGG RESSOR	NUMBER OF OBSERVATIONS	TARGET SPECIES FEEDING GROUP % OF INTER SPECIFIC ATTACKS							
			Ground	Ground/fruit	Ground/bark	Ground/air	Foliage	Flower/foliage	Aerial	Predator
Yellow-throated Miner	Flowe /foliage	68	34	7	0	4	10	19	1	24
White-plumed Honeyeater	Flowe /foliage	179	14	1	14	15	12	21	6	13
Australian Magpie-lark	Gr)und	23	30	0	0	4	4	30	0	30
Willie Wagtail	Gro nd/air	33	30	0	0	0	12	24	0	33

Zebra Finch. Several species too infrequent to be included in the analysis appeared to be the object of particularly high levels of aggression. Raptors and other birds that prey on birds or nestlings and eggs (Collared Sparrowhawk, Wedge-tailed Eagle, Australian Kestrel, Southern Boobook, Grey Butcherbird, Pied Butcherbird, Australian Raven/Little Crow and Australian Magpie) were frequently attacked. So, too, were species whose distribution overlapped dense populations of White-plumed Honeyeaters, namely the Black-faced Cuckoo-shrike, White-browed Woodswallow, Grey Shrike thrush and Rufous Songlark (Chapter 4).

Aggression was recorded in nine species near their nests. Nest defence accounted for a minor portion of total aggression by the aggressive White-plumed Honeyeater (2%), Willie Wagtail (5%) and Australian Magpie (14%), but was more important in the Australian Magpie-lark (25%). Nest defence was a major cause of aggression in relatively non-aggressive species, for example, the Black-faced Cuckoo-shrike (50% of aggressive encounters), Black Honeyeater (100%), Little Corella (83%), Tree Martin (67%) and White-breasted Woodswallow (25%).

No aggressive behaviours were observed during periods of extreme heat (40-45°C). Birds tended to sit still, sometimes panting and with wings outstretched.

Aggressive behaviour at drinking points was uncommon. Only five of the 44 species recorded drinking at the site (Chapter 7), Little Friarbird, White-plumed Honeyeater, Yellow-throated Miner, Australian Magpie-lark and Rufous Songlark, behaved aggressively at drinking points. Frequently, birds of several species, including the above five, drank without confrontation.

Most acts of aggression involved only one or two individuals attacking or chasing. Instances of group aggression involving three or more birds working together were most common in the White-plumed Honeyeater (21% of aggressive acts recorded for this species). Group aggression or mobbing by the White-plumed Honeyeater was directed chiefly at large predators including the Grey Butcherbird, Pied Butcherbird, Collared Sparrowhawk and Southern Boobook. Mobbing involved up to 10 individuals in a single incident and was accompanied by frequent alarm calls. Of the other significantly aggressive species at the site, mobbing accounted for 13% of aggression in the Yellow-throated Miner, 4% in the Australian Magpie-lark, but was not recorded in the Willie Wagtail.

8.4 Discussion

In this study, levels of aggression were high in residents and migrants compared with nomads. Numbers of migrants were too low to discern any marked differences between species. Only certain resident species, the White-plumed Honeyeater, Yellow-throated Miner, Australian Magpie-lark and Willie Wagtail were highly aggressive.

Most of the notably non-aggressive species fed and moved in flocks. A lack of aggression in flocking species is typical of arid as well as mesic (e.g. Morse 1970, Partridge & Ashcroft 1976, Keys & Pugatkin 1990) areas. Personal observations suggest that the lack of aggression noted in birds at Peery during periods of extreme heat is also found in the avifauna of more mesic areas of eastern Australia in heatwave conditions. Such a disparity in levels of aggression found in different species does not support the contention that a lack of aggression is a social adaptation of arid zone birds to a harsh environment (Davies 1982). However, the especially aggressive species were largely associated with relatively mesic habitats within the study area.

Abundant species have a greater chance of being attacked than rare species simply because they are encountered more frequently. When account was taken of the varied densities of potential target species, the White-plumed Honeyeater, Yellow-throated Miner, Willie Wagtail and Australian Magpie-lark appeared to be indiscriminately aggressive to other birds. Each of these aggressive species attacked both larger and smaller birds. Most species and individuals attacked were not potential competitors for food. This lack of discrimination is in contrast to Woinarski's (1984) finding in more mesic forest and woodland, that honeyeaters, including the White-plumed Honeyeater, selectively pursued species, such as pardalotes, with whom they compete for food. Because aggression was indiscriminate, birds whose distributions overlapped most with those of aggressive species were attacked most frequently.

Of greatest consequence for birds of this community is the aggressive behaviour of the White-plumed Honeyeater. The White-plumed Honeyeater was easily the most numerous of the aggressive species (Chapter 3). It concentrated in eucalypt woodland fringing major drainage lines (Chapter 4), the most mesic and most productive habitat in the study area. Eucalypt woodland supported higher densities of perennial trees and shrubs (Chapter 4) and

offered birds more foraging and nesting opportunities than other habitats. It taps subterranean water and is, to a certain extent, buffered from the stresses of short-term droughts. The waterholes in major drainage lines are, apart from springs and overflow lakes which only occur rarely, the most permanent natural source of water for birds in the arid zone.

Eucalypt woodland supporting high densities of White-plumed Honeyeaters was largely bereft of small birds. Many small species, such as the Chestnut-rumped Thornbill, Yellow-rumped Thornbill, Crimson Chat, White-fronted Honeyeater, Black Honeyeater and White-winged Triller, were not recorded in eucalypt woodland with high concentrations of White-plumed Honeyeaters (Chapter 4). The White-winged and Variegated Fairy-wrens only occurred in conjunction with high numbers of White-plumed Honeyeaters where thickets of Lignum *Muehlenbeckia florulenta* provided shelter. The distribution of the ground-dwelling Rufous Songlark only coincided with that of the White-plumed Honeyeater where ground layer vegetation provided dense cover. Small birds may have been absent from these areas because they did not offer suitable habitat. However, a number of plant species in which these birds fed elsewhere occurred in these areas (Chapter 5). It is likely that many small birds were excluded from what is seemingly the richest and most stable habitat, and most likely a drought refuge, by the persistent aggressive behaviour of White-plumed Honeyeaters. Cases of indiscriminate interspecific aggression leading to the exclusion of species have been documented in more mesic environments in two larger colonial honeyeaters, the Noisy Miner *Manorina melanocephala* (Dow 1977) and Bell Miner *M. melanophrys* (Loyn *et al.* 1983, Clarke 1984), and noted in the similar-sized and semi-colonial Fuscous Honeyeater *Lichenostomus fuscus* and White-naped Honeyeater *Melithreptus lunatus* (Davis & Recher 1993). The White-plumed Honeyeater, like these other four honeyeaters, forms dense populations in suitable habitat (Chapter 4) and has a similar diet, taking manna, honeydew and lerps, as well as insects (Paton 1980), from eucalypt foliage (Chapter 5).

Aggression is costly in terms of time and energy. Presumably, in aggressive species, such costs are outweighed by the benefits incurred. As Dow (1977) suggested for the Noisy Miner, the White-plumed Honeyeater may be able to forage more efficiently in areas with fewer competitors and predators. Where the species occurs in high densities the individual cost of aggression may be small. A comparative study of the ecology of the White-plumed

Honeyeater in habitats in which it is the dominant species and in marginal habitats, in which it is relatively uncommon, could be helpful. While there might be difficulties due to differences in food availability, such a study may help to elucidate the benefits of persistent and concentrated displays of aggression for the White-plumed Honeyeater.

In the bird community overall, the functions of aggression were varied. Some aggressive interactions were associated with competition for nest sites and breeding territories, and the defence of nests. The Apostlebird and Australian Magpie-lark, for example, build mud-nests which are placed in similar situations (Chapter 6). Five of the six aggressive interactions noted between Apostlebirds and Australian Magpie-larks occurred within 10m of an active Australian Magpie-lark nest. Whitemore (1981) suggested that Apostlebirds may prey on and even usurp nests of Australian Magpie-larks. Galahs and Little Corellas also have similar nesting requirements. All aggressive encounters between these species appeared to be disputes over ownership of hollows in River Red Gums. A number of species were territorial when nesting. Nests of Willie Wagtail and Australian Magpie-lark, for example, were spaced along strips of creekline habitat and encounters between adjacent nesting pairs of the same species were aggressive. The migratory White-winged Triller is strongly territorial (Immelmann 1966). The high incidence of intra-specific aggression between males at the site can be related to the establishment of territories prior to nesting. In addition to localised displays of aggression near nests, birds attacked potential predators of nests and adult birds wherever encountered, for example butcherbirds, raptors, Australian Ravens and Little Crows.

Drinking water, apparently, was not a resource that many birds defended. Unlike nests, there is no cost to birds in producing drinking water. The amount of water lost to other birds would be small compared to that lost to evaporation. Further, it is a transient resource and water used by an individual will not necessarily be within its territory. The White-plumed Honeyeater was one of the few species to behave aggressively at a drinking point. An investigation of drinking behaviour (Chapter 7) showed that only White-plumed Honeyeaters resident in the immediate vicinity of a drinking point behaved aggressively. Aggressive individuals frequently chased other White-plumed Honeyeaters which had travelled up to 6km or more to find water. The aggressive individuals were probably defending a general territory, as much as the water itself.

The lack of aggression observed in many, but not all, arid zone species, may be a consequence of the nature of their food resources rather than the energetic cost of aggression. The arid zone avifauna is dominatec by species which feed wholly or partly on the ground (Chapter 5). Ground feeders often form flocks and range widely in search of seeds and/or invertebrates. Their food is distribu ed on such a large scale that it may be impossible to defend it. In this variable environment, the availability of food for these birds, especially seed-eaters, is likely to fluctuate betweer periods of scarcity and super-abundance. In contrast, eucalypts, the chief food source of 'White-plumed Honeyeaters, may harbour a resource which it is worthwhile and feasible to defend. These eucalypts are concentrated in major drainage lines and provide a food supply that is comparatively stable, but that may be easily depleted by other foliage gleaners. Though indi criminate, the aggressive behaviour of White-plumed Honeyeater may still be adaptive if it leads to the total or partial exclusion of other species, including those which overlap in re ource use and those which are predators of the White-plumed Honeyeater.

Overall differences betw en residents, migrants and nomads in levels of aggressive behaviour can be related to the diffc rent spatial and temporal scales at which they use food resources. Nomads tend only to occur when food resources are super-abundant and leave an area when resource levels decline (Chapter 3). For nomads there is thus no need to defend food resources aggressively. Reside its, and to a certain extent migrants, must persist when food levels decline. The costs of aggression would be worthwhile for residents and migrants that, as a result of their aggressive behaviour, are able to obtain a greater share of limited resources.

Appendix 8.1 Incidence of aggression in the Peery avifauna. Numbers in table are total number of acts of aggression recorded between each aggressor and target species. Weights (Wt) are derived from banding data from the site and published literature including Forshaw (1981), Rogers et al. (1986, 1990).

AGGRESSOR	Wt(g)	Whistling Kite	Collared Sparrowhawk	Spotted Harrier	Brown Falcon	Wedge-tailed Eagle	Australian Hobby	Australian Kestrel	Peaceful Dove	Diamond Dove	Crested Pigeon	Galah	Little Corella	Budgerigar	Mallee Ringneck	Mulga Parrot	Blue Bonnet	Pallid Cuckoo	Horsfield's Bronze Cuckoo	Southern Boobook	Australian Owlet Nightjar	Red-backed Kingfisher	Sacred Kingfisher	Brown Treecreeper	Variegated Fairy-wren	White-winged Fairy-wren	Spiny-cheeked Honeyeater	Yellow-throated Miner	Singing Honeyeater
TARGET SPECIES →		770	134	612	550	3700	253	169	54	33	229	318	702	27	114	63	88	96	26	287	47	51	44	27	8	8	45	56	25
Little Corella	702		1									5																	
Cockatiel	91													1															
Mulga Parrot	63															1													
Blue Bonnet	88																												
Variegated Fairy-wren	8																												
White-winged Fairy-wren	8																									1			
Spiny-cheeked Honeyeater	45																										1	1	2
Little Friarbird	67																										1		
Yellow-throated Miner	56					1					2	1		1	3	1	2	1		2	1				1		5	11	
Singing Honeyeater	25																										2	2	
White-plumed Honeyeater	18		8			1		3	1	3									1	4			2	4	4		8	26	
White-fronted Honeyeater	17														1												1		
Black Honeyeater	10																												
Pied Honeyeater	26																										1		
Crimson Chat	11									1																			
Chestnut-rumped Thornbill	7																												
Chestnut-crowned Babbler	50										1																		
Grey Shrike-thrush	65																												
Australian Magpie-lark	89	1		1																							1	3	
Willie Wagtail	20		2				1	1																	1				
Black-faced Cuckoo-shrike	107																												
White-winged Triller	25												1									1							
White-breasted Woodswallow	43							1																					
White-browed Woodswallow	35							1																				3	
Black-faced Woodswallow	34																					1							
Grey Butcherbird	92																												
Pied Butcherbird	144																			1									
Australian Magpie	255		1																	1									
Australian Raven/Little Crow	525	4			1	2																							
White-winged Chough	372					2																							
Apostlebird	122														2		1												
Tree Martin	15																											1	
Rufous Songlark	24																												
TOTAL SPECIES:		2	6	1	1	4	1	4	1	2	2	2	1	2	3	2	2	1	1	4	1	2	1	1	3	1	8	7	1
NUMBER OF ATTACKS:		5	16	1	1	6	1	6	1	4	3	6	1	2	6	2	3	1	1	8	1	2	2	4	6	1	20	52	2

Aggressor (rows) × Target species (columns). Target species weights shown in parentheses.

AGGRESSOR	White-plumed Honeyeater (18)	White-fronted Honeyeater (17)	Black Honeyeater (10)	Pied Honeyeater (26)	Crimson Chat (11)	Striated Pardalote (10)	Chestnut-rumped Thornbill (7)	Yellow-rumped Thornbill (8)	Chestnut-crowned Babbler (50)	Grey Shrike-thrush (65)	Restless Flycatcher (21)	Australian Magpie-lark (89)	Willie Wagtail (20)	Black-faced Cuckoo-shrike (107)	White-winged Triller (15)	Spotted Bowerbird (132)	White-breasted Woodswallow (43)	White-browed Woodswallow (33)	Black-faced Woodswallow (34)	Grey Butcherbird (92)	Pied Butcherbird (144)	Australian Magpie (255)	Little Crow/Australian Raven (525)	White-winged Chough (372)	Apstlebird (120)	Tree Martin (15)	Rufous Songlark (24)	Zebra Finch (12)	TOTAL SPECIES
Little Corella																													2
Cockatiel																													1
Mulga Parrot																													1
Blue Bonnet																													1
Variegated Fairy-wren																													1
White-winged Fairy-wren																													9
Splay-cheeked Honeyeater	3	1		1			1	1	1																				
Little Friarbird	1	1		1	1																								27
Yellow-throated Miner	6								6				3	4	2		1				3		8		3				
Singing Honeyeater	40	1			1	2	1			21	2	1	23	11	2	2	1	6	1	10	4		2	2	3	2		8	36
White-plumed Honeyeater					1															1									
White-fronted Honeyeater					1																								
Black Honeyeater					1																								
Pied Honeyeater																													
Crimson Chat							1																						
Chestnut-rumped Thornbill		3	1	1																	1			1			1	1	
Chestnut-crowned Babbler																						1							
Grey Shrike-thrush												2	1	3								1							3
Australian Magpie-lark	1							1	1				1									2	2		4				1
Willie Wagtail	1	1																			1	4	6		3				13
Black-faced Cuckoo-shrike														1						1		2	2	1					2
White-winged Triller															⌐								3						6
White-breasted Woodswallow													1																3
White-browed Woodswallow												1	1										2	1	1				3
Black-faced Woodswallow																							3						3
Grey Butcherbird																													1
Pied Butcherbird																													1
Australian Magpie												1											1	1	2		1		1
Australian Raven/Little Crow																								1			2		5
White-winged Chough												1									1				1				4
Apostlebird												2											1	1			1		4
Tree Martin												2																	2
Rufous Songlark		1																					1	1			2		2
TOTAL SPECIES:	6	5	1	3	5	1	3	2	3	1	1	6	7	5	3	1	2	1	1	3	6	3	7	3	6	1	4	3	**56**
NO. OF ATTACKS:	52	7	1	3	5	2	3	2	8	21	2	14	41	20	11	2	2	6	1	12	11	7	24	4	14	2	11	10	