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A DECLINE IN THE NUMBER OF WEDGE-TAILED SHEARWATERS BREEDING ON RAINE ISLAND?

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Between December 1995 and December 2000 there was an apparent decline of greater than 40 per cent in the number of occupied Wedge-tailed Shearwater *Puffinus pacificus* burrows on Raine Island. The estimated census of approximately 3 550 burrows or crevice nests in December 1995 declined to estimates of approximately 2 360 and 1 570 Shearwater burrows or crevice nests in December 1998 and 2000 respectively. Burrow occupancy was approximately 56 per cent in 1998 and 66 per cent in 2000, with eggs or chicks found in 43 per cent of burrows in 1998 and 49 per cent in 2000. Yet the number of occupied ledge crevice nests found in 1998 (130) and 2000 (131) was approximately double that found in 1995 (60). The overall decline may be due to turtle nesting activities on the northern ridge however further investigation is needed to verify this.

INTRODUCTION

Raine Island (144°01'E, 11°37'S) is a 28 hectare coral cay situated approximately 100 kilometres ENE of Cape Grenville in northern Queensland. Its oceanic nature is evidenced by the diverse range of seabirds it supports (Gourlay *et al.* 1993), amongst which, is a major breeding colony of Wedge-tailed Shearwaters *Puffinus pacificus* (Lavery 1969).

The island consists of a vegetated ridge covered in low shrubs, grasses, succulents and creepers. This ridge surrounds a central depression, which was once mined for phosphorous and is almost devoid of vegetation (Fig. 1). The high soil strength of the depression virtually excludes Shearwater burrowing (Neil and Dyer 1992) except where earth mounds remain. The phosphate ridge drops away sharply at its outer edge with ledges reaching approximately 2 metres on the eastern end of the island. A few Shearwaters nest in the grassed verge that surrounds the ridge in seasons when turtle nesting does not interfere.

The aim of this research was to repeat, in December 1998 and 2000, the December 1995 Raine Island Wedge-tailed Shearwater study (Dyer 1999) in order to ascertain any change in Shearwater burrow estimates or burrow/nest occupancy rates during that period. Counts of occupied ledge crevice nests, burrow census estimates and occupancy rates were established for habitats previously identified by Jeff Miller for the purpose of continuing bird studies (Fig. 1).

METHODS

Inspection of ledge crevice nests

Although all crevices that could support a Shearwater nest and could be reached with the burrowscope were inspected (Dyer and Hill 1991; Dyer and Aldworth 1998), only occupied ledge crevices were recorded. It was impossible to determine whether or not unoccupied crevices constituted an unoccupied nest, and therefore any rate of occupancy for ledge crevices would be little more than an educated guess.

Burrow census estimates

All burrows in the grass verge were counted and their contents recorded. Estimates of burrow numbers were established for the northern vegetated ridge (NVR); the north section of the southern vegetated ridge (NSVR); the southern section of the southern vegetated ridge (SSVR); and in 1998 only, an earth mound in the central depression. These estimates were established by counting burrows in 4 metres wide × 5 metres long contiguous quadrats that formed transects traversing the previously identified habitats (see Fig. 1). Ratio population estimates with standard errors (Cochran 1977) that account for different transect sizes (Norton-Griffiths 1978) were established. An aggregation of the estimates for the individual habitats was determined to provide an estimate for the whole island.

The ratio, R, of total number counted, Y, to the total sample area, Z, was found ($R = \Sigma y/\Sigma z$). The estimated population, $\hat{Y}$ was calculated by multiplying the ratio of the mean number of burrows (nests or birds) counted per transect (i.e. the area of the island divided by the total number of transects on the island) by the area of the island. The standard error was also found as follows:

The variance between burrows counted in all transects:

$$s_y^2 = 1/(n-1)(\Sigma y^2-[(\Sigma y)^2/n])$$

The variance between the area of all transects:

$$s_z^2 = 1/(n-1)(\Sigma z^2-[(\Sigma z)^2/n])$$

The covariance between the burrows counted and the area of each transect:

$$s_{yz} = 1/(n-1)(\Sigma yz-[\Sigma y*\Sigma z/n])$$

The best estimate of the population variance then was calculated:

$$\mathrm{Var}\ \hat{Y} = (N(N-n)/n)(s_y^2-2Rs_{yz}+R^2s_z^2)$$

The standard error of the estimated number of burrows:

$$\mathrm{SE}\ \hat{Y} = \sqrt{(\mathrm{Var}\ \hat{Y})}$$
$$\hat{Y} = \pm\ 2\mathrm{SE}\ (\hat{Y})$$

Where: N = total number of transects;

n = number of transects in sample;

Z = the area of the census zone: island or habitat;

z = area of any one transect;

y = burrow count in any one transect; and

R = ratio of burrows counted to sample Results

Sample areas used for analyses were taken from the digitized map (Fig. 1) in order to standardize the area of the sample and the total area of habitats. This facilitates between season comparison and reduces bias in the final estimates.

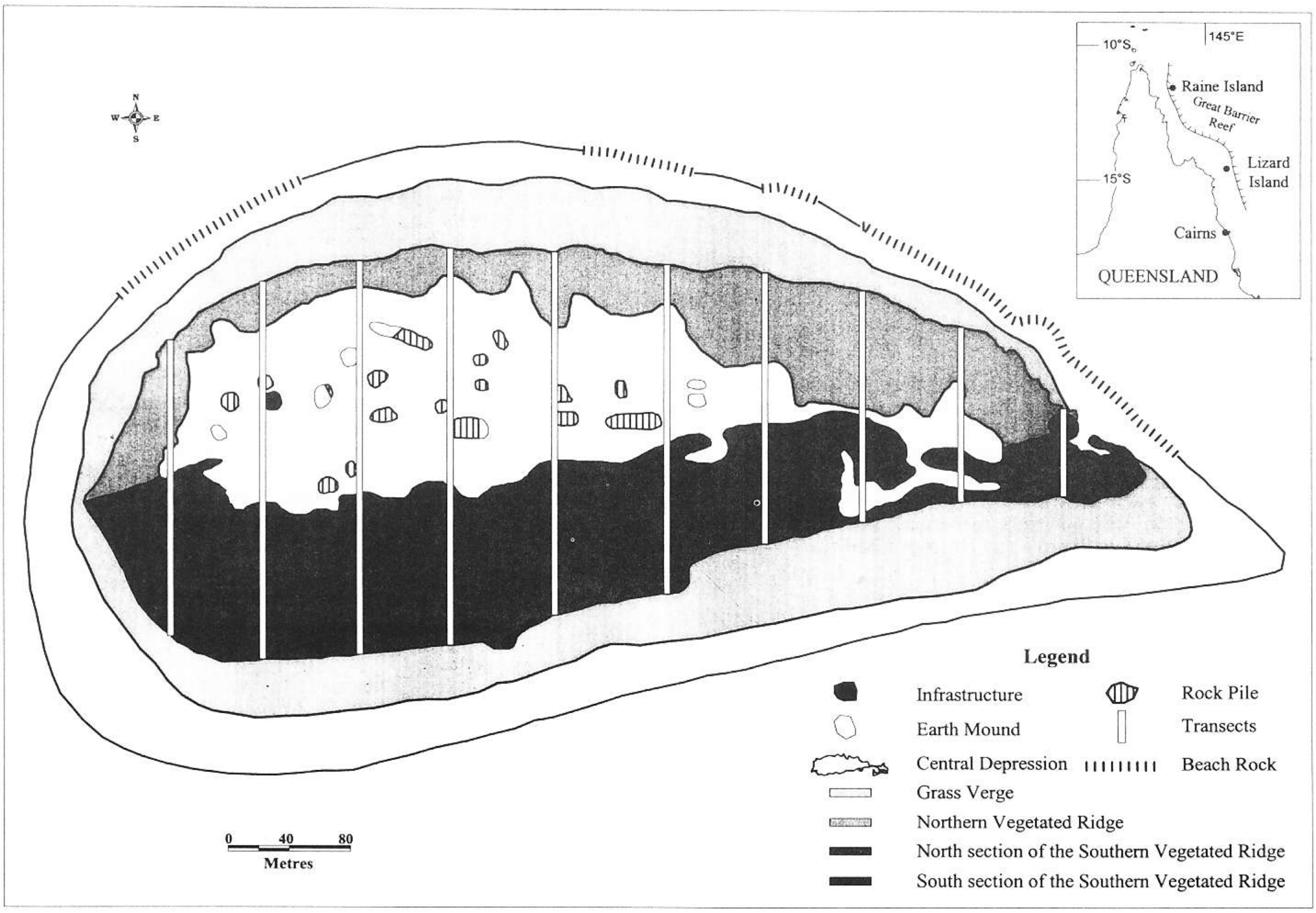

Figure 1. *Sketch map showing the various habitat types and transect location on Raine Island.*

Inspection of burrow contents

The contents of all burrows within transects were ascertained unless the burrows were too convoluted or had obstructions that inhibited effective use of the burrowscope. Occupancy rates, the stage of the breeding cycle, and usage of nest lining were determined.

RESULTS

Counts and occupancy in ledge crevice nests

There was a relatively high level of usage of ledge crevices in December 1998 with 130 crevices being occupied by Shearwaters. Of these, in nests where the presence or absence of a chick or egg could be confirmed (N = 126), 61 (i.e. 48.4%) contained an egg or chick. Similarly, 61.6 per cent (N = 112) of the occupied crevices inspected in December 2000 contained an egg or chick (See Table 1). Chicks (<12 days old) were found in 4 ledge crevices in December 1998 and in 11 crevices in December 2000.

TABLE 1

Wedge-tailed Shearwater *Puffinus pacificus* occupancy of ledge cavities on Raine Island.

Wedge-tailed Shearwater	No. 1998	percentage 1998	No. 2000	percentage 2000
Bird only	27	20.8	14	10.7
Two birds only	9	6.9	2	1.5
Two birds, lined	5	3.8	4	3.1
Two birds, egg, lined	2	1.5	2	1.5
Two birds, chick	1	0.8	0	0
Two birds, chick, lined	0	0	1	0.8
Two birds — egg? chick? lined?	0	0	1	0.8
Bird, lined	24	18.5	23	17.6
Bird, egg	2	1.5	2	1.5
Bird, egg, lined	52	40.0	54	41.2
Bird, chick, lined	1	0.8	8	6.1
Bird, lined — egg? chick?	4	3.1	8	6.1
Bird — egg? chick? lined?	0	0	10	7.6
Egg, lined	1	0.8	0	0
Chick, lined	2	1.5	2	1.5
TOTAL	130	100	131	100

Burrow census estimates

In December 1995, Dyer (1999) estimated 3 551 burrows, including occupied ledge crevices and the burrows found in the grass verge but excluding burrows in the central depression. Replicating this method resulted in comparative burrow estimates for December 1998 of 2 361, and for December 2000 of 1 574 (see Table 2). In 1995 an additional 167, and in 1998 an additional 115 (se = 81%) burrows estimated for the earth mounds in the central depression, could be added to the above estimates. In December 1995 the sample was based on one quadrat, thus no standard error was established. The large standard error for 1998 results from the small sample size. The estimate

TABLE 2a

Wedge-tailed Shearwater burrow census estimates for individual habitats: South Section of the Southern Vegetated Ridge (SSVR); North Section of the Southern Vegetated Ridge (NSVR); Northern Vegetated Ridge (NVR); Ledge Crevices; and Grassed Verge.

Habitat (Area of Habitat in m²)	Burrow Estimate 1998	Se	Burrow Estimate 2000	Se
SSVR (30 370)	735	21%	523	34%
NSVR (22 960)	827	24%	719	24%
NVR (26 550)	799	37%	192	46%
Habitat	Burrow Count 1998	Se	Burrow Count 2000	Se
Ledge Crevices (occupied only)	130	0%	131	0%
Grassed Verge (53 240)	0	0%	9	0%
Island Census Total	2361*		1574*	

* These estimates do not include burrows in the central depression and they incorporate standard errors of habitat estimates thus standard errors of approximately 30 per cent.

TABLE 2b

Sample areas per transect for habitat types.

Transect	SSVR	NSVR	NVR	Depression	Transect Area
1.00	335.10	95.31	278.22	77.34	785.97
2.00	212.94	210.44	116.18	459.27	998.83
3.00	213.22	218.69	66.53	539.53	1 037.97
4.00	231.83	199.35	67.96	546.63	1 045.77
5.00	207.92	208.06	190.48	349.51	955.97
6.00	208.94	195.25	98.98	362.27	865.44
7.00	124.37	197.68	229.41	158.00	709.46
8.00	25.42	175.11	304.40	100.15	605.08
9.00	92.72	0.00	156.82	208.94	458.48
10.00	148.35	0.00	11.21	73.13	232.69

for the earth mounds is therefore of little help, except to draw attention to the fact that the comparative estimates presented here which exclude the central depression are probably underestimated by about 200 burrows.

The burrow census estimate for 1998 falls within the standard error for that of 1995, and the estimate for 2000 falls within the standard error for the 1998 estimate. Nevertheless, the estimate for 2000 falls outside the error range for 1995, thus the burrow estimate for 2000 indicates that the declining trend represents a real reduction in the number of burrows on the island between 1995 and 2000 (Fig. 2).

By applying the proportion of active burrows (i.e. those housing a chick or an egg) to estimates for the individual habitats and then aggregating these, it was established that approximately 1 097 and 804 burrows or crevice nests supported breeding activities in 1998 and 2000 respectively. Taken at face value this suggests a reduction of approximately 27 per cent in two years, and, based on a similar estimate of breeding burrows for 1995 of 1 472, of 45 per cent in five years.

Burrow occupancy

In 1998, 45.4 per cent of burrows were unoccupied. Breeding activities, confirmed by the presence of an egg or chick, were evident in 42.8 per cent of burrows. In

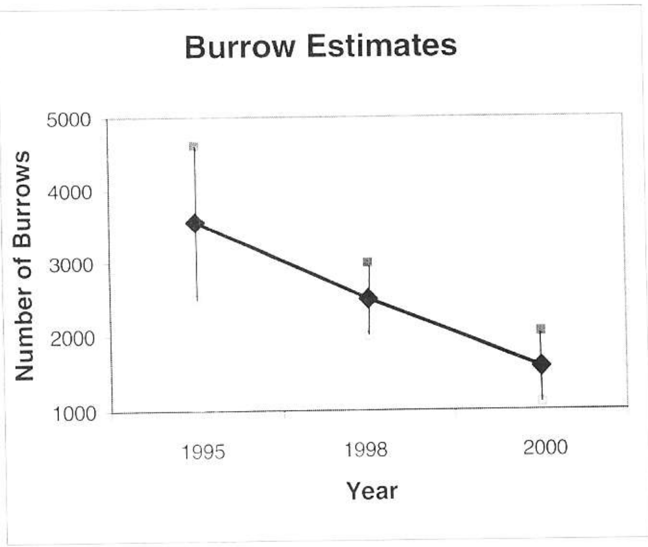

Figure 2. *Burrow estimates ± se for December 1995, 1998 and 2000.*

addition to the 1.7 per cent of burrows that were occupied by an adult Wedge-tailed Shearwater but where it was not possible to ascertain the presence or absence of a chick, a further 10.1 per cent of burrows housed an adult bird. Burrows with a bird incubating an egg in a lined chamber constituted the majority (38.7% of all burrows) of occupied burrows (45.4%) (See Table 3). Relatively few birds were present in unlined burrows (4.2%) with only 2.5 per cent of burrows housing birds incubating eggs in unlined chambers. In addition, two burrows (one in the central depression) contained chicks that were thought to be about 12 days old, and one burrow in the central depression contained an unaccompanied egg.

In 1998 burrow occupancy was similar in the different habitat types ($X^2 = 0.565$, df = 3, p = 0.904, n = 133). There was, however, a significant difference in burrow occupancy between transects ($X^2 = 143.346$, df = 18, $p < 0.001$, n = 133). Only 13 of 133 burrows were found in the four most easterly transects. No burrows were found in the grass verge in 1998.

TABLE 3

Contents of Wedge-tailed Shearwater burrows, in December 1998, in the different habitats on Raine Island: South Section of the Southern Vegetated Ridge (SSVR); North Section of the Southern Vegetated Ridge (NSVR); Northern Vegetated Ridge (NVR); Ledge Crevices; and Grassed Verge.

Wedge-tailed Shearwaters	nvr		nsvr		ssvr		Total	
	No.	%	No.	%	No.	%	No.	%
Unoccupied Burrows	12	10.1	24	20.2	18	15.1	54	45.4
Occupied Burrows	No.	%	No.	%	No.	%	No.	%
Bird only	1	0.8	3	2.5	1	0.8	5	4.2
Bird, lined	0	0.0	6	5.0	1	0.8	7	5.9
Bird, egg	0	0.0	1	0.8	2	1.7	3	2.5
Bird, lined — egg? chick?	2	1.7	0	0.0	0	0.0	2	1.7
Bird, lined, egg	9	7.6	20	16.8	17	14.3	46	38.7
Egg, lined	1	0.8	0	0.0	0	0.0	1	0.8
Chick, lined	0	0.0	0	0.0	1	0.8	1	0.8
All Occupied	13	10.9	30	25.2	22	18.5	65	54.6
Total	25	21.0	54	45.4	40	33.6	119	100

In 2000, 32.6 per cent of burrows were unoccupied and it was impossible to see whether or not an additional burrow (1.1%) was occupied. Occupancy was found in 66.3 per cent of burrows, with an egg or chick found in 49.4 per cent of burrows. In addition to the 2.2 per cent of burrows that housed an adult but where the other burrow contents could not be established due to the limitations of the burrowscope, a further 14.6 per cent of burrows housed one or two (n = 3) adult birds. Burrows with a bird incubating an egg in a lined chamber constituted the majority (40.5%) of all occupied burrows (See Table 4). Relatively few birds were present in unlined burrows (7.9%) with only 5.6 per cent of burrows housing birds incubating eggs in an unlined chamber. Only one burrow contained an unattended chick. Three of the nine burrows found in the grassed verge in 2000 supported an adult incubating an egg in a lined chamber.

TABLE 4

Contents of Wedge-tailed Shearwater burrows, in December 2000, in the different habitats on Raine Island: South Section of the Southern Vegetated Ridge (SSVR); North Section of the Southern Vegetated Ridge (NSVR); Northern Vegetated Ridge (NVR); Ledge Crevices; and Grassed Verge.

Wedge-tailed Shearwaters	Habitat nvr		nsvr		ssvr		Total	
Unoccupied Burrows	No.	%	No.	%	No.	%	No.	%
Unoccupied?	0	0.0	0.0	0.0	1	1.1	1	1.1
Unoccupied	5	5.6	17	19.1	7	7.9	29	32.6
Occupied Burrows	No.	%	No.	%	No.	%	No.	%
Bird only	0	0.0	3	3.4	4	4.5	7	7.9
Two birds only	0	0.0	0	0.0	2	2.2	2	2.2
2 Birds, lined	0	0.0	1	1.1	0	0.0	1	1.1
2 Birds — lined? egg? chick?	0	0.0	1	1.1	0	0.0	1	1.1
Bird, lined	1	1.1	2	2.2	0	0.0	3	3.4
Bird, egg	0	0.0	0	0.0	5	5.6	5	5.6
Bird — lined? Egg? chick?	1	1.1	0	0.0	0	0.0	1	1.1
Bird, lined, egg	3	3.4	22	24.7	11	12.4	36	40.5
Bird, lined, chick	1	1.1	1	1.1	0	0.0	2	2.2
Egg, lined	0	0.0	0	0.0	1	1.1	1	1.1
All Occupied	6	6.7	30	33.7	23	25.8	59	66.3
Total	11	12.4	47	52.8	31	34.8	89	100

No significant influence was established between burrow occupancy and the various habitat types ($X^2 = 2.046$, df = 2, p = 0.360, n = 88) in December 2000. Even though only 17 of the 89 burrows were found in the four most easterly transects in the vegetated ridge, the transect location did not appear to influence burrow occupancy ($X^2 = 11.292$, df = 14, p = 0.663, n = 88).

DISCUSSION

While the 1998 data collection methods closely resembled those of 1995, the predation activities of seagulls in 2000 precluded daytime work. Very early in the research seagulls learned to follow researchers in order to access Booby *Sula* sp. eggs that were left unprotected when Boobies were disturbed by the presence of the research team. Though predation was anticipated, it was not witnessed by the researcher in 1995, or by her and others in 1998 (David Neil, pers. comm.). The fact that data were collected at night in 2000 may explain the higher occupancy of burrows in this year as birds return to the island at night to roost. Even so, the data pertaining to breeding would not be affected.

Accessing the earth mounds in the central depression disturbs many nesting Brown Boobies *Sula leucogaster* and Masked Boobies *Sula dactylatra* with eggs and young chicks. This explains the small sample in this habitat in 1995 and in 1998. The large standard error for this habitat combined with the predation by seagulls in December 2000 contributed to the decision not to include this habitat in 2000.

A higher proportion of the crevice nests contained an egg or a chick in December 2000 than in 1998 but neither matched the proportion (79%) of occupied ledge crevices containing eggs or chicks in 1995 (Dyer 1999). The difference infers a higher proportion of roosting birds that may be explained by the inclement weather conditions experienced during the 1998 and 2000 trips. Even though usage of the crevice nests had increased in absolute terms from 47 in 1995 to 61 and 69 in 1998 and 2000 respectively, the difference does not account for the reduction of burrows or burrow usage in the vegetated ridge.

By doubling the estimated number of burrows containing an egg or chick, an estimate of the breeding population can be established. This results in estimates of 2 194 (1998) and 1 608 (2000) breeding birds on Raine Island. The Shearwater population estimates for December 1998 and 2000 then, fell within the expected range of between 1 000 and 5 000 birds (Taplin and Blaber 1993). This study however, in replicating the 1995 study, provides comparative estimates thus suggesting a more reliable trend that indicates an overall decline.

The habitat that appeared to suffer the greatest decline was the northern vegetated ridge. The higher rate of ledge occupancy may indicate a transition in habitat usage, but there were insufficient breeding ledge nests to account for the decline in the northern vegetated ridge. This narrow habitat that supported burrow estimates of 915, 799 and 192 in the respective trips is relatively exposed to Green Turtles (*Chelonia mydas*). As 1999 had one of the highest numbers of breeding turtles on record there was substantial disturbance to birds (Paul O'Neill, pers. comm.). The low number of burrows in this habitat could result from the high number of turtles present in the previous year. Shearwaters display strong site fidelity, habitually returning to specific islands to breed, so Shearwater breeding rates could follow a natural cycle that reflects the turtle activity on the island. When eggs or chicks are lost through burrow disturbance Shearwaters are unlikely to re-lay because egg deposition accounts for 30–38 per cent of the reproductive cycle (Warham 1990).

Other natural phenomena such as weather conditions and food supply related to fluctuating patterns in the currents could also impact on the population. It is too early to determine whether or not the decline exposed by this research is part of a natural cycle, however, the degree of the decline over a short period suggests that managers should be concerned and that further investigations are warranted.

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BOOK REVIEW

Canberra birds: A Report on the First 18 Years of the Garden Bird Survey.

Philip A. Veerman. 127 pp. Soft cover. Available from the author at 24 Castley Circuit, Kambah ACT 2902. Pveerman@pcug.org.au. Also available from BOCA and Birds Australia. Price $19.00 plus $3.50 p&p.

On receiving a scientific book this reviewer starts at the references which indicate the homework the author has done. In this case they run to more than 3½ pages so he passes that test.

It is usual for scientific works to be read by a couple of one's peers prior to publication and to be edited. In this case, neither of these has been done, much to the detriment of the work. Efficient editing would have reduced the volume of the first two sections of the book and made them more readable.

The book is in three sections. The first is a general discussion of the data (49 pages). The second is a species listing and discussion which goes to page 90 while the individual species figures extend to page 106 with 8 species analysed per page. There are 6 appendices.

The annual histograms and the 18 year graphs are the real meat of the book and sharply illustrate the month by month status and the 18 year trend. It is shown that the development of gardens in Canberra has changed the behaviour of quite a few species. In some cases the observations are of small numbers which makes these of little consequence. In others with larger numbers the increases are obvious e.g. the Australian King Parrot, Sulphur-crested Cockatoo, the Crimson Rosella, the Australian Magpie and the Australian Raven.

Those passerines which appear to be in decline in eastern Australia, probably because of land clearance, are represented by small numbers as they do not adapt to suburbia but the general trend is there. The fact that Canberra is virtually surrounded by the Nature Park appears also to be a contributing factor to the wealth of birds. It appears from these records that birds are more abundant where the site is near an area of natural vegetation.

Two hundred and eighteen species were listed on the Garden Bird Charts and 1 151 charts were submitted by 277 individuals. Only 8 sites were covered for the full 18 years but the data are very comprehensive because of the large number of contributors. 87 species were recorded as breeding.

The author has worked tirelessly for many years on the analysis of the data for the Annual Bird Reports published in Canberra Bird Notes.

Canberra is a relatively compact, small city and it is doubtful if a similar study could be made in any of the State capitals. This is an aspect which makes this analysis of the data of the Garden Bird Charts all the more valuable. The author acknowledges that the material he is working with belongs to the Canberra Ornithologists Group.

This volume is an important contribution to the literature of Australian ornithology. To get a comprehensive picture it demonstrates that many people must contribute data over a very long period.

Steve Wilson OAM