CHAPTER 2

A SURVEY OF THE POPULATION AND HABITAT OF THE SOUTH AUSTRALIAN GLOSSY BLACK-COCKATOO (*CALYPTORHYNCHUS LATHAMI HALMATURINUS*)

ABSTRACT

The endangered South Australian glossy black-cockatoo (*Calyptorhynchus lathami halmaturinus*) is restricted to Kangaroo Island, South Australia. A 1993 survey investigated the size, structure, and distribution of the population, the quantity and quality of foraging habitat, and the effects of a 1991 fire that burned most habitat on the Island's west coast. A total of 136 birds were counted, mostly on the Island's western north coast. Among birds identified by age and sex, 90% were adult and there were 1.4 adult males per female. Drooping sheoak (*Allocasuarina verticillata*) woodland covered about 0.3% of the Island, primarily on the western north coast. Grazing by sheep in much of the habitat reduced but did not prevent sheoak regeneration. Most habitat patches showed foraging signs, but most individual sheoak trees did not. The best predictor of foraging intensity across habitat patches was average seed mass per cone. The 1991 fire burned 14% of the Island's foraging habitat, and no cockatoos were found in the burned areas. The fire killed most sheoaks but not most eucalypts, and burned sheoak woodland was regenerating from both seedlings and basal shoots. The results confirm that the

population is critically small, and vulnerable to local events such as wildfires. They also suggest that both habitat quantity and quality are limiting factors for the subspecies.

INTRODUCTION

The glossy black-cockatoo (*Calyptorhynchus lathami*) is rare throughout its range, and listed as Endangered in South Australia. The isolated South Australian population is now restricted to Kangaroo Island, and has recently been recognized as a subspecies, *C. l. halmaturinus* (Schodde et al. 1993). The first survey estimated the population at 115 - 150 birds in 1980, including fewer than 30 breeding pairs (Joseph 1982). Surveys in 1987 and 1988 counted only 15 and 50 birds respectively (Joseph 1988, pers. comm.). The subspecies appears to have an excess of males and a low recruitment rate, and may be in decline (Joseph 1982; Garnett 1992).

The glossy black-cockatoo is almost completely dependent on the seeds of casuarina trees (genus *Allocasuarina*) for food, and its distribution is closely tied to that of its food trees (Forshaw 1981). Habitat loss apparently caused the disappearance of *C. l. halmaturinus* from the mainland (Joseph 1989), and while agricultural development was delayed on Kangaroo Island, most native vegetation has been cleared there as well. The amount and quality of foraging habitat has not been documented previously. The Island's west coast was formerly a population center for the subspecies (Terrill & Rix 1950; Condon 1967; Glover 1968), but most of this region was burned by a bush fire in October 1991.

The present study investigates the population's size, structure, and distribution as of 1993. It also estimates the amount of foraging habitat on Kangaroo Island, quantifies its characteristics, and examines how it is affected by livestock and fire. Finally, it examines what habitat characteristics affect the distribution of foraging activity.

METHODS

The survey focused on areas containing drooping sheoak (*Allocasuarina verticillata*) woodland, because all reports agree that glossy black-cockatoos on Kangaroo Island feed almost exclusively on the seeds of these trees (Cleland & Sims 1968; Joseph 1982; Pepper 1993). Between 21 May and 14 June of 1993, two teams of two and three workers visited a total of 61 localities (Table 2.1). These included all localities covered in previous surveys (Joseph 1982, pers. comm.), some additional areas of drooping sheoak woodland, and all locations where glossy black-cockatoos have been recorded more than once since 1980 (Chapter 9). All place names used are from the South Australian Department of Lands 1:50,000 topographic map series, second edition. For regional comparisons I divided the Island into six regions as follows: West Coast (Cape Borda to Cape du Couedic), Western North Coast (east of Cape Borda to Cape Cassini), Eastern North Coast (east of Cape Cassini to Prospect Hill), South Coast (Cape du Couedic to Prospect Hill), Dudley Peninsula (including coastal areas), and Interior (all locations more than five km from the coast, excluding the Dudley Peninsula). All regions except the South Coast contained drooping sheoak woodland and previous records of the cockatoos, and were included in the survey.

Cockatoo Census

We surveyed all localities for glossy black-cockatoos. We designated each as either first or second priority based on previous records, and visited first priority localities during the first or last two hours of daylight when the birds are most active. We searched visually, listened for calls and feeding sounds, and looked for foraging signs. At localities where we only heard calls we recorded no more than two birds, as we could only determine reliably whether more than one bird was calling. Upon locating a flock we stayed in the area until we believed we had counted the entire flock. We tried to locate nests when we saw indications of possible nesting, but did not include nestlings in the census.

For birds we saw clearly enough, we recorded age and sex categories as follows: adult male (little or no yellow on head, solid red tail panel); adult female (yellow markings on head, fully barred tail panel); or immature (head brown or with only fine spotting of ear coverts, tail at least partially barred). We classified immature birds as males if they had any completely unbarred tail feathers, or gave the "Kwee-chuck" call and associated "Bow Display" given by males (Chapter 3). We classified immature birds as female if they did not show any indications of being male, and were accompanied by an adult male.

Habitat Survey

The habitat survey included all localities containing at least one hectare of drooping sheoak woodland (N = 56; Table 2.1, Fig. 2.1). Habitat patches that were not continuous or nearly so were defined as separate localities. At each locality we estimated the area of drooping sheoak woodland (and the burned area if applicable) from sketches on 1:50,000 maps. We estimated canopy cover as the percentage of the ground covered by a projection of the drooping sheoak canopy, and noted whether the locality was accessible to livestock, whether drooping sheoak seedlings were present, and whether the locality contained any potential nesting trees. Based on measurements of five nest hollows (unpub. data), we defined potential nesting trees as eucalypts with an apparent hollow entrance at least 10 m above ground and at least 15 cm high by 10 cm wide. (We could not determine from the ground whether these openings actually led to suitable nest sites.)

We used feeding signs to estimate the amount of recent foraging in each locality. Glossy black-cockatoos drop shredded seed cones when they feed, and these remain visible on the ground for several months (Joseph 1982; Clout 1989). We walked through each locality on a path that maximized the number of female drooping sheoaks encountered, and recorded the number with and without foraging signs (average N = 312). As an index of foraging intensity we used the percentage of trees with feeding signs, and as an index of the total amount of recent foraging we multiplied foraging intensity by patch size in hectares.

At each locality we established a sampling plot centered at an arbitrary point in a representative part of the habitat patch. We used burn sampling plots in recently burned areas and vegetation sampling plots elsewhere (see below). At several localities that were partly burned or showed marked variation we established two plots (Table 2.1).

Vegetation sampling plots

In each vegetation sampling plot we recorded the number of male and female drooping sheoaks and other trees and shrubs within a 10 m diameter circle (average N = 26.5 sheoaks). Sheoak dominance was defined as the percentage of trees and shrubs in the plot that were drooping sheoaks. For the first 10 cone-bearing drooping sheoaks encountered while sweeping clockwise through the plot starting from due north, we measured girth at 50 cm high and estimated the number of cones containing seeds. For larger trees we estimated the cone crop by counting cones on 3-4 representative limbs and multiplying the average by the number of limbs. For trees with more than one stem, total girth was calculated as the square root of the sum of the squares of the separate girths.

(This derived measure has the same cross-sectional area as the separate stems combined, assuming cylindrical stems). We estimated the density of seed cones per m^2 as an indicator of the amount of food available. To do this we multiplied the number of sheoak trees in the plot by the mean number of cones per tree, and divided by the plot area.

To measure seed cone characteristics, we collected 10 unopened cones from each of the three female drooping sheoaks nearest to the center of the plot that held enough cones. To reduce the potential for sampling bias, we collected the first cones our hands fell on without looking. We pooled the thirty cones from each plot and dried them in a drying oven for 48 h at 40° C, causing them to release their seeds. We then weighed the seeds and cones separately to the nearest milligram on an electronic balance.

Burn sampling plots

In each burn sampling plot we counted the number of drooping sheoaks within a 10 m diameter circle that were undamaged, damaged, and killed by the fire. We counted the number of drooping sheoak seedlings within a 2 m diameter circle, and measured the heights of the 20 seedlings nearest the center. We also classified the 10 nearest eucalypts taller than 10 m as undamaged, damaged, or killed. (Trees taller than 10 m were judged large enough to provide shelter and roosting sites.) To increase our sample of drooping sheoak trees we walked through each locality scoring the condition of each tree we encountered until we had sampled at least 100 trees (mean = 199). For at least 50 live re-sprouting sheoaks (or as many as we could find, mean = 66), we recorded the type of re-shooting (e.g., basal, epicormic, or root suckering), and whether the new shoots had been grazed.

I used the SYSTAT software package (Wilkinson 1992) for statistical analyses. To improve normality I log transformed the measures of patch size, sheoak density, sheoak girth, seed cones per tree, and cones per m^2, and used an arcsine transformation for the percentage of trees foraged (Sokal & Rohlf 1981). All statistical tests were two-tailed unless otherwise noted.

Table 2.1. List of surveyed localities, ordered geographically

Sampling plots: b = burn sampling plot, v = vegetation sampling plot (two letters represent two sampling plots in different parts of the habitat patch), * = not included in habitat survey.

Region Locality	Map	Grid reference	Area (ha)	Sampling plots
West Coast				
Sandy R.	Vennachar	PA475210	30	b
Breakneck R.	Vennachar	PA455233	30	b
West Bay	Vennachar	PA411276	90	b b
Headland north of Vennachar Pt.	Vennachar	PA394304	35	b v
Ravine des Casoars at West Bay track	Borda	PA459364	17	b v
Western North Coast				
Harveys Return	Borda	PA485427	40	v v
Harveys Return gully, upstream	Borda	PA501418	6	v
Ravine des Casoars at 'Ravine'	Borda	PA524412	3	v
Cape Torrens	Borda	PA556452	31	v
De Mole R.	Snug Cove	PA615457	2	v
Gully 0.5 km W of Covenys Gully	Snug Cove	PA628475	12	v
Covenys Gully	Snug Cove	PA632474	18	v v
Gully W of Whale Gully	Snug Cove	PA638478	3	v
Whale Gully	Snug Cove	PA644475	6	v
Kangaroo Gully	Snug Cove	PA657478	1	v
Waterfall Cr.	Snug Cove	PA725484	25	v
Billygoat Gully	Snug Cove	PA729488	30	v
Castle Gully	Snug Cove	PA745493	40	v
Sheoak Gully	Snug Cove	PA759497	30	v
Valley Cr.	Snug Cove	PA765490	*	*
Western R., west branch	Snug Cove	PA790477	20	
Western R., east branch	Snug Cove	PA794491	24	v
Pebbly Beach Gully	Stokes Bay	PA838492	5	v
Middle R. near Sall Cr.	Stokes Bay	PA896475	74	v
Little King George Gully	Stokes Bay	PA915514	10	v
Little King George Beach	Stokes Bay	PA912520	5	v
King George Gully	Stokes Bay	PA925514	95	v v
Springy Water Cr.	Stokes Bay	PA960526	31	v
Gully E of Springy Water Cr.	Stokes Bay	PA971542	7	v
Sheoak Cr.	Stokes Bay	PA997525	10	v
Gum Cr.	Stokes Bay	QA006537	58	v
Stokes Bay Cr.	Stokes Bay	QA003552	31	v
Deep Gully	Stokes Bay	QA022550	49	v
Gully W of Hummocky Gorge	Stokes Bay	QA024562	17	v
Gullies NW of McDonnell Hill	Cassini	QA073577	90	v
Large gully NE of McDonnell Hill	Cassini	QA089583	15	v
Eastern North Coast				
Western Cove	Kingscote	QA356418	35	v
Gully N of Ballast Head	Penneshaw	QA530397	2	v
Ballast Head	Penneshaw	QA532390	23	v
Second gully N of American River	Penneshaw	QA520383	27	v
First gully N of American River	Penneshaw	QA515378	5	v
Muston	Kingscote	QA476337	3	v

Table 2.1 (continued).

Region / Locality	Map	Grid reference	Area (ha)	Sampling plots
Dudley Peninsula				
Blue Gum Gully	Penneshaw	QA645392	11	v
Penneshaw residential area	Penneshaw	PA663422	14	v
Penneshaw - 1st gully E of town	Penneshaw	QA667422	24	v
Penneshaw - ridge E of Willson R. Rd.	Penneshaw	QA677423	25	v
'Vernon', near Cuttlefish Bay	Willoughby	TF290410	1	v
Cuttlefish Bay gully	Willoughby	TF304408	2	v
Cape Coutts	Willoughby	TF346383	130	v
Antechamber Bay	Willoughby	TF345375	56	v
Pink Bay Gully	Willoughby	TF399304	10	v
Interior				
Near North West R. and ‘Double J’	Grainger	PA742217	5	v
North West R. at Church Rd.	Grainger	PA721250	*	*
North East R. near ‘Hillview’	Vivonne	PA816245	25	v
Cygnet escarpment S of 'Bark Hut'	Cassini	QA145405	22	v
Cygnet escarpment NW of Parndana C. P.	Cassini	QA072424	56	v
Parndana Cons. Park, NE corner	Cassini	QA109407	3	v
Parndana Cons. Park, SE corner	Cassini	QA112392	8	v
Branch Cr. at Playford Hwy.	Cassini	QA178413	*	*
Cygnet R. E of Ropers Rd.	Cassini	QA249445	*	*
Seddon Conservation Park	Seddon	QA052320	*	*

RESULTS

Cockatoo Population

We counted a total of 136 cockatoos, including 128 seen, six heard, and two seen by other observers just before our arrival (Table 2.2, Fig. 2.1). Forty-four of these were inside National or Conservation Parks. We identified 97 birds by age or sex category, including 36 adult females, 51 adult males, and 10 immature birds. The survey was completed before nestlings normally fledge, and we did not see any dependent juveniles. We found three active nests, one in a dead eucalypt near the Cygnet River and two in the same South Australian blue gum (*Eucalyptus leucoxylon*) near the Western River.

Habitat Characteristics

The surveyed localities included an estimated total of 1477 ha of drooping sheoak woodland, 36% of which was inside National or Conservation Parks. Drooping sheoak was the dominant tree species at most localities, but formed an understory under sugar gums (*Eucalyptus cladocalyx*) in some areas. The sex ratio for drooping sheoaks was 1.08 males per female. The number of seed cones per tree increased linearly with girth (Fig. 2.2). The number of seed cones per square meter also increased with mean tree girth ($R = 0.32$, $N = 45$, $p = 0.03$). Table 2.3 summarizes additional habitat characteristics.

Table 2.2. Sightings of glossy black-cockatoos, ordered geographically.

See Table 2.1 for geographical details. * = localities included in 1980 census (Joseph 1982, pers. comm.). Age & sex: F = adult female, M = adult male, IF = immature female, IM = immature male, I = immature (sex unknown), U = unknown age and sex.

				Number by age and sex					
Region	Locality	Date	No.	F	M	IF	IM	I	U
Western North Coast									
	Ravine des Casoars at ‘Ravine’	3/6	2						2
*	De Mole R.	9/6	2						2
	Waterfall Cr.	29/5	11		1				10
	Billygoat Gully	28/5	8	3	3				2
	Castle Gully	28/5	2	1	1				
	Valley Cr.	7/6	2						2
*	Western R., east branch	8/6	34	14	19		1		
	Pebbly Beach Gully	26/5	9	4	5				
*	Middle R. near Sall Cr.	26/5	19	4	6				9
*	Little King George Gully	27/5	2						2
	Sheoak Cr.	28/5	4	2	2				
*	Gum Cr.	28/5	15	3	5				7
*	Deep Gully	30/5	3	1	2				
Eastern North Coast									
*	American River	25/5	7		1	1	3	2	
Dudley Peninsula									
*	Penneshaw residential area	14/6	4		1	1	2		
Interior									
	Cygnet escarpment S of 'Bark Hut'	30/5	5	2	3				
	Cygnet R. E of Ropers Rd.	27/5	2	1	1				
	North East R. near 'Hillview'	21/5	2	1	1				
	North West R. at Church Rd.	31/5	3						3
Totals:			136	36	51	2	6	2	39

Regional variation

Table 2.4 summarizes regional variation in habitat characteristics. In comparisons among sample plots, the West Coast averaged fewer cones per female sheoak than the Dudley Peninsula, and fewer cones per m^2 than the Dudley Peninsula, Interior, and Western North Coast (ANOVA with Tukey HSD test, $p < 0.05$ for each pairwise comparison). It also had a lower percentage of sheoaks relative to other species than each of the other regions ($p < 0.005$ for each). The five regions did not vary significantly in density or girth of drooping sheoak trunks, or in sheoak canopy cover. Some characteristics of seed cones also varied regionally. Eastern North Coast localities had smaller cones than either the Interior or the Western North Coast (ANOVA with Tukey HSD test, $p < 0.05$). Regional variation in seed mass per cone was marginally significant (ANOVA, $p = 0.045$), but no two regions were significantly different in post-hoc pairwise tests. Seed mass as a percentage of total cone mass did not vary significantly between regions.

Both the percentage of localities grazed by livestock and the percentage containing drooping sheoak seedlings varied between regions (chi-square test, $p < 0.02$ for each; Table 2.4). When all localities were pooled, those with livestock were less likely to contain seedlings (chi-square test, $p = 0.016$). Localities with livestock also contained fewer saplings. Sheoaks smaller than 15 cm in girth were less than half as common in grazed versus non-grazed localities (Fig. 3).

Impact of fire

An estimated 91% (187 ha) of the drooping sheoak on the West Coast was burned in the 1991 fire. The mean mortality rate for sheoaks was 74% (range 39 - 100%).

Table 2.3. Summary of habitat characteristics

For the first three variables data points represent localities; for the last eight variables data points represent vegetation sampling plots.

	Mean	SD	Min	Max	N
Size of drooping sheoak stand (ha)	26.4	27.0	1	130	56
Sheoak canopy cover	65%	24%	5%	100%	53
Percentage of female sheoaks foraged	12%	17%	0%	63%	55
Sheoak density (trees / 100 m^2)	33.7	25.8	3.0	112.0	47
Sheoak dominance (% of trees & shrubs)	93%	15%	33%	100%	46
Mean sheoak girth (cm)	43.8	26.6	15.0	154.8	48
Mean number of cones per female tree	354	379	27	2180	47
Seed cone density (cones / m^2)	83.5	93.9	5.4	511.5	46
Mean cone mass without seeds (g)	5.24	0.88	3.38	7.19	46
Seed mass per cone (mg)	317	79	136	489	46
Seed mass as % of total cone mass	5.7%	0.8%	3.3%	7.4%	47

Data points represent localities.

	Present	Absent	Percent present
Livestock	24	31	44%
Drooping sheoak seedlings	30	16	65%
Potential nesting habitat	34	20	63%
Foraging signs	43	13	77%

Table 2.4. Regional variation in habitat characteristics.

Values for the last six measures are averages across localities. Only measures with statistically significant variation among regions are shown.

	West Coast	North coast, western	North coast, eastern	Dudley Peninsula	Interior	All regions combined
Number of localities	5	30	6	9	6	56
Total habitat area (ha)	202	788	95	273	119	1477
Localities w/ livestock	0%	47%	0%	88%	50%	44%
Localities w/ sheoak seedlings	100%	52%	100%	60%	80%	65%
Drooping sheoak dominance	52%	94%	95%	96%	96%	93%
Cones per tree	75.6	335.7	305.1	598.2	218.0	353.6
Cones per m^2	4.5	43.7	17.9	75.2	38.6	43.4
Cone mass without seeds (g)	4.4	5.4	4.3	4.8	6.0	5.2
Seed mass per cone (mg)	198	329	258	312	358	317
Foraging intensity	0.3%	14.3%	5.8%	1.0%	30.5%	11.9%

Eighty-three percent of the surviving sheoaks were damaged, and on almost all of these all seed cones had opened and the only live foliage was on basal shoots. Thus only 4% of the female sheoaks in burnt areas held seeds. An average of 27% of re-shooting drooping sheoaks had been cropped by grazing (range 0 - 95%). Drooping sheoak seedlings were present at a mean density of 9.4 per m^2 (range 0 - 21), and a mean height of 18.5 cm (range 3 - 52). In the southern section of West Bay the fire was extremely hot, and in this area of about 50 ha, all drooping sheoaks were dead and no seedlings were present. Eucalypts taller than 10 m (primarily sugar gums) suffered a mean mortality rate of 18% (range 0 - 30%). Among surviving eucalypts 82% were damaged, and 34% retained no pre-fire foliage.

At the Ravine des Casoars we saw 11 feral goats, and there was evidence of heavy grazing on regenerating sheoaks. Of 64 live sheoaks that had put out new shoots since the fire, 95% were cropped, compared with an average of 19% at other burn sampling plots (chi-square = 143, $p < 0.005$). Mortality among trees that had put out new shoots was 60% (N = 68), in contrast to 29% at other plots (N = 373) (chi-square = 24.2, $p < 0.005$). Many seedlings were also cropped, and some had apparently died as a result. Compared to other burned localities with seedlings, their average height was only 11.2 cm versus 20.3 cm, and their density was only 1.6 per m^2 versus 18.2.

Distribution of Feeding Signs

Foraging signs were visible at 43 of the of the 56 localities (77%). Across all localities, a mean of 12% of female sheoaks showed foraging signs, and among localities with any feeding signs, the mean was 16%. The index of total foraging activity was highly correlated with the number of cockatoos counted at each locality (Fig. 2.4). The mean foraging index was also highly correlated with the number of cockatoos counted in each region (Spearman rank-order correlation, $R_s = 1.00$, N = 5, one-tailed $p < 0.01$).

Foraging intensity (as measured by the percentage of seed bearing trees with feeding signs) varied considerably between regions, with regional differences accounting for 33% of the observed variation (ANOVA, $p < 0.001$). The best predictors of foraging intensity among both localities and regions were seed cone characteristics. Across localities foraging intensity was positively correlated with seed mass per cone ($R = 0.37$, $N = 46$, $p = 0.012$), and ratio of seed to cone mass ($R = 0.34$, $p = 0.022$), but not with total cone mass. (The two seed measures were inter-correlated: $R = 0.75$, $p < 0.001$.) Foraging intensity was also correlated with seed mass per cone across regions (Fig. 2.5). Foraging intensity was negatively correlated with the density of sheoak trunks ($R = 0.30$, $p = 0.049$), but was not associated with patch size, drooping sheoak dominance, canopy cover, seed cones per m^2, mean tree girth, or mean number of cones per tree ($p > 0.05$). Foraging intensity also did not vary significantly with the presence or absence of potential nesting habitat, livestock, or drooping sheoak seedlings (T tests, $p > 0.05$ for each).

DISCUSSION

Cockatoo Population

Population size

The total of 136 cockatoos counted is close to the previous published count of 115 (Joseph 1982). The number at each locality also corresponded well with the extent of foraging signs, thus we generally found cockatoos where the evidence indicated they should be. Because the survey spanned 24 days, some error could have resulted from cockatoos moving between localities during the survey. However, this should not have caused a directional bias because cockatoos that moved would be equally likely to be missed or counted twice. Some birds might have been missed because the survey was conducted in May-June, during the breeding season. Joseph (1982) noted that the number of cockatoos at several localities increased markedly after July, near the end of the breeding season. In a similar trend, average flock size peaked in August in a large collection of unpublished records from Kangaroo Island (Chapter 9). The cockatoos' tendency to congregate at the end of the breeding season might make surveys most accurate then. Even given that some birds may have been missed, the total population probably includes fewer than 200 individuals.

Although the count from this survey is higher than previous efforts (Joseph 1982, 1988, pers. comm.), this does not indicate that the population is growing. The current survey was more complete because it was based on more information and covered more localities. In fact the comparison may suggest a declining population, because the current survey found only 86 cockatoos in the same localities where Joseph (1982, pers. comm.) counted 115 cockatoos in 1980.

Population structure

Adult females are virtually always paired (Joseph 1982, pers. obs.), and the count of 36 adult females thus provides a minimum estimate for the number of mated pairs in the population. If the 39 birds not identified by age and sex contained the same proportion of adult females as the identified birds, the total number of mated pairs would be 50. The documentation of a 1.4:1 sex ratio confirms previous suggestions of a substantial excess of males in the population (Garnett 1992; Schodde et al. 1993). Schodde et al. (1993) also noted an apparently male-biased sex ratio in *C. l. erebus* in the Dawes Range. This bias may result from greater female mortality, which has been reported for other cockatoo species (e.g., Carnaby's cockatoo, Saunders 1982; Major Mitchell cockatoo, Rowley & Chapman 1991; galah, Rowley 1990). The sex ratio bias we observed is greater than reported for these other species. The low proportion of only 10% immature birds suggests that reproductive success is low, even allowing for the fact that females lay only one egg. Because immature plumage is retained for about two years by females and up to seven years by males (Courtney 1986), the ten immature birds we counted represent several years of reproduction.

Distribution Patterns

The distribution of cockatoos we observed agrees well with previous surveys, differing mainly in the species' absence from the West Coast after the 1991 fire. The Western North Coast is clearly the population center, as Joseph (1982) reported earlier. This region is important both because it includes most of the known foraging habitat, and because it had the highest density of cockatoos per hectare of habitat. This survey, as well as earlier efforts, focused almost entirely on areas of drooping sheoak woodland, and would therefore be misleading if the cockatoos spent any significant amount of time away from these trees. However, all reports agree that glossy black-cockatoos rarely stray from the *Allocasuarina* trees they feed on (Cleland & Sims 1968; Forshaw 1981; Joseph 1982, 1989; Blakers et al. 1984; Clout 1989; Sindel & Lynn 1989; Schodde et al. 1993; Pepper 1993, Chapter 9).

The correlation between the distribution of foraging signs and cockatoos suggests that surveys of feeding signs may be a useful supplementary method for monitoring glossy black-cockatoo populations. Although feeding signs provide less information than direct counts, they are easier to find and less variable on a daily basis, and they require less skill and time to observe accurately.

The distribution of habitat only partly explains the distribution of cockatoos, as they fed in some patches much more intensively than others. Variation in foraging intensity was also correlated with the quality but not the quantity of seed cones. This is consistent with the strong preferences shown by glossy black-cockatoos for feeding in specific trees. *C. l. lathami* in New South Wales prefer *Allocasuarina littoralis* trees with high ratios of seed to cone mass (Clout 1989), and *C. l. halmaturinus* on Kangaroo Island prefer *A. verticillata* trees with high ratios of seed to cone mass and high seed mass per cone (Chapter 4). Thus, the qualities preferred in individual trees also affected distribution among habitat patches. The same pattern persisted at a regional level (Fig. 2.5), indicating the importance of food quality in determining the cockatoos' distribution even on a wider geographic scale.

Other factors may also affect distribution patterns. Foraging intensity was lower on the Dudley Peninsula than expected on the basis of seed cone quality (Fig. 2.5), and this may reflect the region's lack of large eucalypts for shelter and roosting. The cockatoos also seemed to avoid dense young stands of re-growth, as reflected in the negative correlation between foraging intensity and tree density, and a (nonsignificant) positive correlation with tree girth. This preference could arise either because of the slightly higher food density in more mature stands, or because densely packed young trees impede the cockatoos' flight.

Habitat

Regional variation

Drooping sheoak was unevenly distributed across the Island, and was also unevenly affected by human activity. The earlier and denser human settlement of the Island's eastern end explains why more habitat patches on the Dudley Peninsula had livestock and fewer had drooping sheoak seedlings than in other regions. More extensive felling of eucalypts there also probably contributed to the absence of potential nesting habitat from most localities in the Dudley Peninsula and the Eastern North Coast.

Although habitat on the West Coast appeared to differ considerably from other regions, this may have been an artifact of only two unburned remnants being available for vegetation sampling. One, on the headland north of Vennachar Point, had very thin soil and trees with an atypical low bushy structure, and is apparently not used by the cockatoos. Therefore the results may not reflect typical habitat characteristics for the West Coast.

Habitat loss and fragmentation

Habitat destruction has clearly caused the cockatoos' decline in South Australia (Barrett 1949 p. 20; Cleland & Sims 1968; Garnett 1992). Drooping sheoak woodland has nearly vanished from much of the mainland (Bishop & Venning 1986; Cooke 1987). It has obviously been cleared substantially from Kangaroo Island as well, as agricultural land borders most patches outside parks. However, the loss is hard to quantify because there is little information on the previous extent of drooping sheoak woodland. Earlier studies of native vegetation mention drooping sheoak, but do not map its distribution (e.g., Wood 1930; Baldwin & Crocker 1942; Northcote & Tucker 1948). Systematically mapping the entire Island would produce a more accurate figure, but the current estimate of 1477 ha makes it clear that suitable habitat is sparse, comprising only 0.34% of Kangaroo Island's total area. Land clearance has slowed greatly in recent years, but because cockatoos are long-lived it is not clear whether the population has yet fallen to a stable size, or still exceeds the Island's reduced carrying capacity.

Because glossy black-cockatoos are relatively sedentary (Forshaw 1981; Blakers et al. 1984), they may also be vulnerable to habitat fragmentation as distinct from habitat loss. The fact that foraging intensity was not lower in smaller patches suggests that the cockatoos do use small patches. However, I did not attempt to analyze the combined effects of patch size and distance from other patches.

Effects of grazing

Drooping sheoak is palatable to hoofed stock (Churchill 1983), and grazing by sheep can prevent its regeneration. Because drooping sheoaks are short-lived, this has led to their disappearance from parts of South Australia (Bishop & Venning 1986). Grazing by sheep clearly reduces drooping sheoak regeneration on Kangaroo Island, as grazed localities contained fewer saplings and seedlings (Fig. 2.3). Regeneration was not completely suppressed, however, and with few exceptions drooping sheoak woodland did not appear to be senescing and dying off in stocked areas, as it has on the nearby Eyre Peninsula (Bishop & Venning 1986). Higher rainfall or the absence of rabbits on Kangaroo Island may be responsible for this difference (Cooke 1987).

Even in habitat areas without livestock, however, grazing pressure may affect sheoak regeneration after fires. Feral goats were apparently responsible for a sharp reduction in the survival of both trees and seedlings in burnt habitat in the Ravine des Casoars. This suggests that grazing by livestock may also prevent regeneration after fires, even in areas where it is not usually detrimental. The protection of burned drooping sheoak woodland from grazing by both domestic and feral livestock may therefore be an important conservation measure.

Impact of fire

The 1991 fire effectively eliminated the west coast of Kangaroo Island as habitat for glossy black-cockatoos. If the headland north of Vennachar Pt. is excluded as unsuitable foraging habitat, only 4% of the habitat on the West Coast was left unburned. This represents a temporary loss of about 14% of the subspecies' total foraging habitat on Kangaroo Island. Although mortality was much higher among drooping sheoaks than sugar gums, drooping sheoaks may be replaced more quickly because they grow faster. There is little published information on the response of drooping sheoak to fire. After a major fire on the West Coast in 1970, glossy black-cockatoos first reappeared eight years later, and flocks of up to 20 were recorded after 13 years (C. Baxter, pers. comm.). Nineteen months after the 1991 fire, the widespread presence of basal re-shooting and new seedlings suggested that most stands may eventually return to roughly the same areas they covered previously. This is in contrast to a previous report that drooping sheoaks do not re-grow from roots or stems after fires (Bishop & Venning 1986). In the Ravine des Casoars area however, grazing by feral goats apparently suppressed regeneration both by re-shooting and seedlings. The impact of fires on glossy black-cockatoo habitat may depend substantially on the ensuing level of grazing pressure.

A contrasting concern is that suppressing the normal fire regime could prevent the regeneration of drooping sheoak woodland, leading to senescence and reduced seed productivity. There was no evidence that this occurs, however. We do not know the ages of the trees we measured, but the largest were over 200 cm in girth, compared to the 30-45 cm described by Churchill (1983) as typical. Nonetheless, there was no evidence of reduced productivity in older trees or older stands. Standing cone crops continued to increase with trunk girth through the largest trees (Fig. 2.2), and the density of seed cones per unit area was higher in stands with larger trees.

Current Status and Threats

There is no simple criterion for a minimum viable population size, but with fewer than 200 individuals this subspecies would be considered threatened by almost any standard (e.g., Lande & Barrowclough 1987). Because of its small size and limited range, the subspecies is subject to deleterious inbreeding, as well as unpredictable events such as droughts and disease outbreaks. The 1991 fire, which removed approximately 14% of the population's total habitat for perhaps 13 years, highlights this vulnerability.

Loss of habitat is clearly responsible for the subspecies' disappearance from the South Australian mainland (Cleland and Sims 1968; Garnett 1992), and is almost certainly limiting for the Kangaroo Island population as well. The two resources most likely to be limiting are food and nesting cavities. It is difficult to assess whether the food supply is adequate, because quality as well as quantity may be crucial, and the quality of foraging habitat varies substantially. However, observations of flock movements and diet changes coincident with the seasonal ripening of seed cones suggest that food is sometimes limiting (Pepper 1993). A shortage of nest hollows may also affect this population, as it does in other cockatoo species (Saunders et al. 1985; Joseph 1988; Joseph et al. 1991; Emison et al. 1994). The eastern end of the Island (Dudley Penn. and Eastern North Coast) has few large eucalypts, and none of 18 nesting records from the Island are from this area (Chapter 9). Nest boxes erected in 1991 were used successfully by glossy black-cockatoos, but were often occupied by other species, including other cockatoos, brushtail possums, and feral honeybees (unpub. data). This suggests that competition for hollows from other species may also be important. Whether food or nest hollows are limiting may vary between regions. For example, food may be more limiting on the West Coast, while large eucalypts are particularly scarce at the Island's eastern end. Further research is needed to clarify the relative importance to population growth of drooping sheoak woodland, large eucalypts, and nest hollow competition from other species.

ACKNOWLEDGMENTS

This study was funded by the South Australian Department of Environment and Land Management through a grant from the Endangered Species Program of the Australian National Parks and Wildlife Service. Janet Pedler, Marie Anderson, Timothy

D. Male, and Guinnevere E. Roberts helped with the field work. My thanks especially to the latter three, who worked as volunteers under difficult conditions. Lynn Dohle and the Department of Primary Industries provided the drying oven, and Ian Sarson and the Parndana Area School furnished the electronic balance. Gillian Haines helped process and weigh seed cones, Leo Joseph contributed unpublished data and helpful advice, and Terry E. Dennis provided logistical support throughout the study. I gratefully acknowledge the help of these people, and the dozens of land owners that gave permission to work on their properties. The manuscript benefited from discussions with the South Australian Glossy Black-Cockatoo Recovery Team, and comments by Richard D. Alexander, Terry E. Dennis, Gillian Haines, Brian A. Hazlett, Timothy D. Male, John C. Mitani, Robert B. Payne, Guinnevere E. Roberts, Rachel A. Smolker, Barbara B. Smuts, and two anonymous referees.

Figure 2.1. Map of localities included in survey. Open squares represent locations included in habitat survey, open circles represent locations where cockatoos were searched for and not seen, and filled circles are locations where cockatoos were seen.

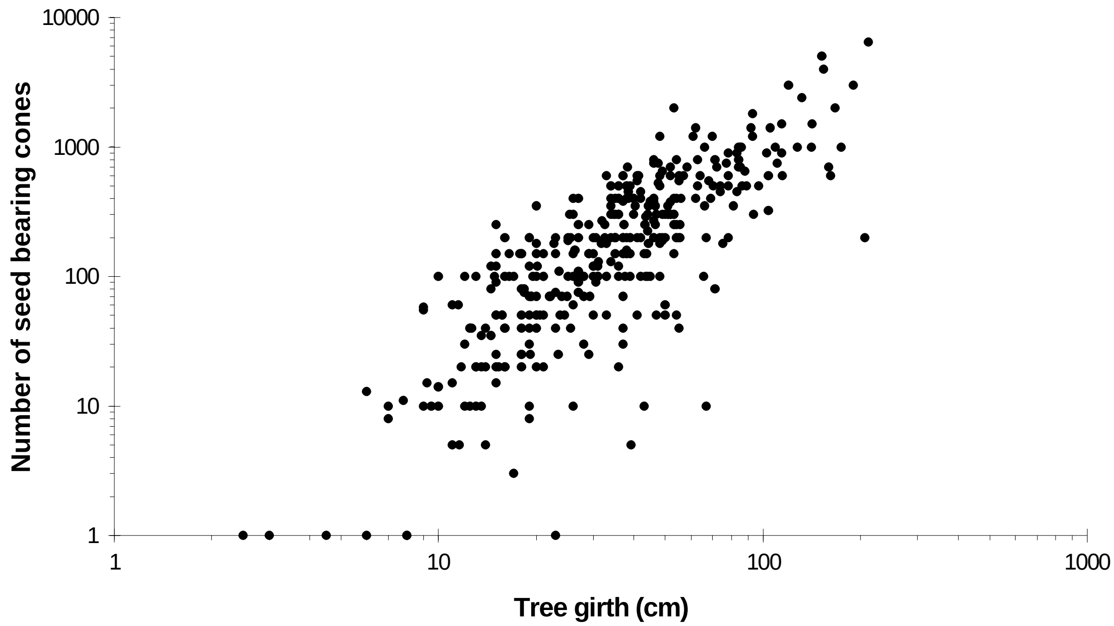

Figure 2.2. Relationship between drooping sheoak trunk girth and standing cone crop. Linear regression: log(cone crop) = -0.91 + 1.68 * log(girth in cm). $R = 0.80$, $N = 383$, $p < 0.001$.

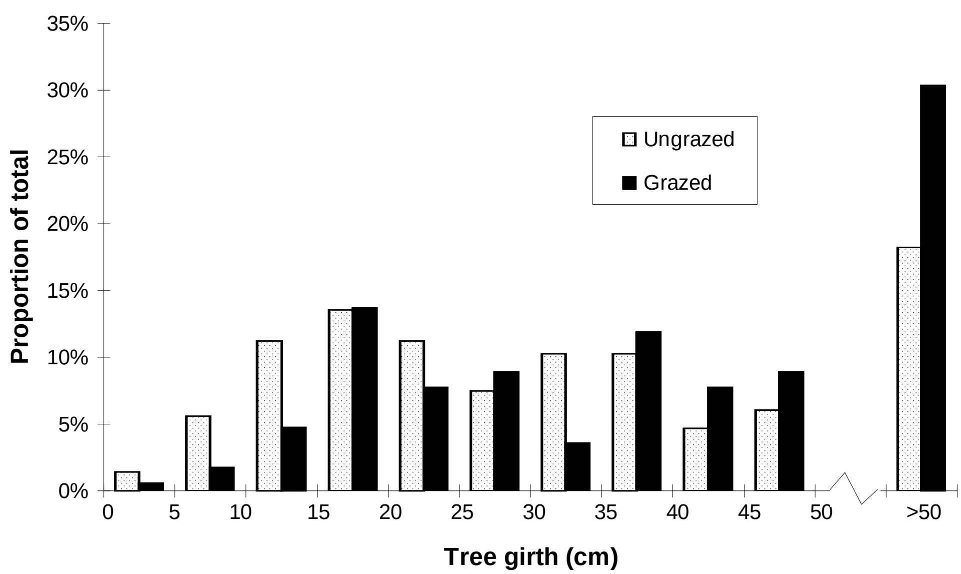

Figure 2.3. Size distribution of drooping sheoaks in grazed versus ungrazed plots.

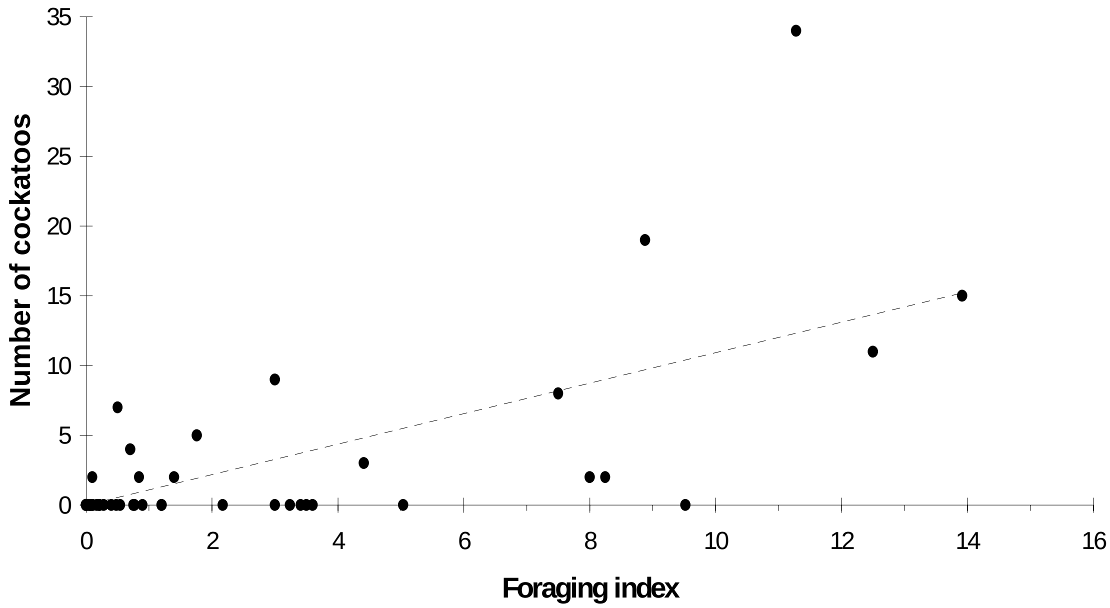

Figure 2.4. Relationship between foraging signs and the number of cockatoos counted in each locality. Foraging index = percentage of seed-bearing sheoaks showing feeding signs multiplied by area in hectares. The linear regression was: (number of birds counted) = 1.09 * (foraging index); R = 0.74, N = 54, p = 0.001.

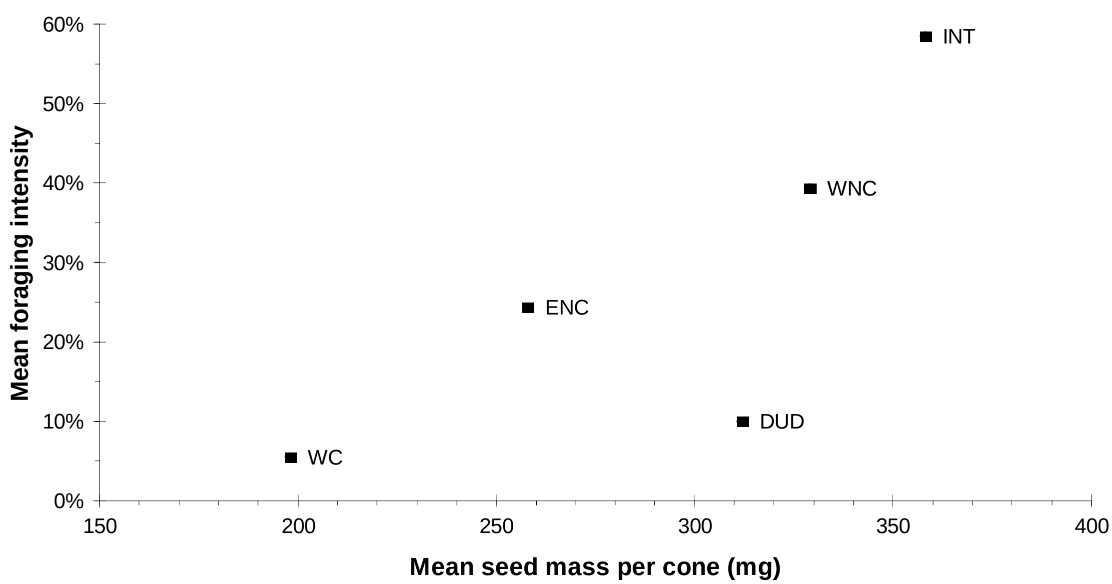

Figure 2.5. Relationship between seed mass per cone and foraging intensity (percent of seed-bearing sheoaks foraged) across regions. Spearman rank-order correlation, R_s = 0.90, one tailed $p < 0.05$. WC = West Coast, WNC = Western North Coast, ENC = Eastern North Coast, DUD = Dudley Peninsula, INT = Interior.

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