ASSESSMENT OF HABITAT VALUES FOR BLACK-COCKATOOS WITHIN THE EASTERN ACQUIRED LANDS AT NEWMONT BODDINGTON GOLD MINE

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1. SUMMARY

Three black-cockatoos occur at the Newmont Boddington Gold (NBG) mine-site in Boddington, Western Australia: Baudin's Cockatoos (*Calyptorhynchus baudinii*), Carnaby's Cockatoos (*Calyptorhynchus latirostris*), and the subspecies Forest Red-tailed Black-Cockatoos (*Calyptorhynchus banksii naso*) [FRTBC]. All three are considered threatened and are listed under State and Commonwealth legislation.

Murdoch University was requested by Newmont Boddington Gold to undertake a study of an area to the east of the NBG mine-site (referred to hereafter as the 'eastern acquired lands'), and to assess the value of this area as (a) feeding habitat and (b) breeding habitat for black-cockatoos. This report provides the results of this study. Murdoch University has conducted several projects at NBG since 2007 that are relevant to this study, and this report should be read in context with reports, publications, and theses relating to these.

This study used two basic approaches. Firstly, vehicle-based surveys were conducted to collect sighting data for black-cockatoos. Secondly, extensive plot-based sampling was used to collect data on the presence of: (a) known black-cockatoo food plants; (b) hollows potentially-suitable for black-cockatoos; and (c) black-cockatoo feeding residues (e.g. damaged fruit husks).

To better examine the relative value of the eastern acquired lands, plot sampling occurred within the four major land uses in the NBG area: (a) native forest (n = 425 plots); (b) livestock paddock with remnant vegetation (n = 75 plots); (c) mine-site rehabilitation (n = 90 plots); and (d) pine plantation (n = 25 plots). Data from previous and concurrent studies at NBG were also considered.

Nature of Use

All three black-cockatoo species use the eastern acquired lands as a feeding habitat. Feeding activity of Carnaby's Cockatoos is likely to occur throughout the year and to generally concentrate on *Banksia* and *Hakea* shrubs, as well as Jarrah and (more occasionally) young Marri fruits. Baudin's Cockatoos appear to peak in abundance in the NBG area during the non-breeding season (about April – September) and to focus on Marri (*Corymbia calophylla*). FRTBC occur year-round at NBG and feed on Marri, Jarrah (*Eucalyptus marginata*), and occasionally Sheoak (*Allocasuarina fraseriana*).

Distributions of the three species are likely linked not only to the availability of food (e.g. flowering/fruiting of food sources), but also to the presence of permanent water sources, particularly during summer. The reliance on water sources may underlie the large number of observations along the eastern edge of the acquired lands (adjacent to paddocks with farm dams) during the summer months (i.e. November – March for this study).

Four probable nest sites for Carnaby's Cockatoos and FRTBC were located within the eastern acquired lands. Several other probable nest sites are located nearby within NBG tenements. These findings indicate that the eastern acquired lands provide suitable breeding habitat, although the factors driving nest site selection (e.g. hollow characteristics, distance to water sources, food availability) require better characterisation.

Food Plant Inventory

Previous flora surveys have recorded the presence of least 30 known food plants for black-cockatoos within NBG tenements and the eastern acquired lands. These food plants include four eucalypts, seven *Banksia* species, and ten

Hakea species. Most of these food sources are ephemeral (e.g. flowering/seeding for brief periods) and/or occur only in small abundances, and therefore will represent only an incidental or short-term food resource at best. The diets of the three species also differ, with Carnaby's Cockatoos consuming the broadest range of food plants.

Murdoch personnel have observed black-cockatoos feeding on, or have identified feeding residues for, sixteen native plant species at NBG within native forest (n = 11 plant species) and mine-site rehabilitation (n = 12 plant species) habitats. We have also observed Carnaby's Cockatoos feeding on pine (*Pinus radiata*) within the Sotico plantation. The majority of feeding observations are, however, of birds feeding on Marri and Jarrah, and these two food sources provide the cornerstone food sources, with pine and proteaceous shrubs also important food plants for Carnaby's Cockatoos.

Feeding Activity Across Land Uses

The feeding activity of black-cockatoos varied across the four major land uses in the NBG area. Feeding activity (as measured by the proportion of plots containing feeding residues) was higher in the two anthropogenic habitats (plantation: n = 25/25 plots, 100%; mine-site rehabilitation: n = 62/90 plots, 68.9%) than in native forest (n = 159/425 plots, 37.4%) or paddock vegetation (n = 23/75 plots, 30.7%).

Differences in the intensity of feeding activity probably relate to the presence, diversity, density, phenology, and nutritive/energetic value of food plants within the different land uses. Studies have yet to be conducted to evaluate the energetic equivalence of the food resources within different feeding habitat, and even if anthropogenic habitats are more profitable habitats, they constitute only a fraction of the landscape around NBG, emphasising the overall importance of food plants within native forest. Nonetheless, the findings do indicate that: (a) feeding on proteaceous shrubs within native forest habitat occurs at low intensities (although there may be seasonal periods of high-intensity feeding on certain species), and (b) mine-site rehabilitation does provide suitable food plants.

Feeding Activity Across Food Plants

We observed feeding residues for nine plant species during plot sampling within native forest and paddock vegetation. These included residues from three eucalypts (Marri, Jarrah, and Yarri *E. patens*), two *Banksia* species (*B. sessilis* and *B. squarrosa*), and three *Hakea* species (*H. prostrata*, *H. undulata*, and *H. varia*). Marri was by far the most commonly observed feeding residue within native forest plots (n = 126 plots, 29.6% of plots). Residues from Jarrah (n = 4 plots, 1.1%), Yarri (n = 1 plot, 0.2%), and Sheoak (n = 5 plots, 1.2%) were very infrequently observed.

The low prevalence of feeding residues for Jarrah contrasts with Biggs (2008), who found a similar prevalence of Jarrah and Marri feed trees at NBG. This difference between the two studies probably reflects inter-annual variation in the flowering (and subsequent fruiting) of Jarrah (and Marri), as well as seasonal variation in fruit quality, factors that will affect the distribution of Baudin's Cockatoos and particularly FRTBCs (FRTBC are likely to be the primary consumers of Jarrah fruits in the NBG area). Differences in the persistence of Jarrah and Marri residues could also be a contributing factor, but these areas have not been burnt for >5 years and both Jarrah and Marri residues should persist (i.e. be recognisable as feeding residues) for at least a year.

Thus these findings do indicate that feeding on Marri was far more intensive than for Jarrah across at least a one-year period (prior to the study) and across the extent of the native forest landscape of the study area. Jarrah feeding residues occurred more frequently in paddock plots than in native forest plots, suggesting differences in the quality

or availability of Jarrah fruits and/or differing distributions of FRTBC between these two land uses. Sighting data also suggest that FRTBC may prefer vegetation within or near to paddocks.

Feeding residues from proteaceous shrubs were observed infrequently within native forest plots (n = 29 of 425 plots, 6.5%), with most residues coming from *B. sessilis* (n = 12 plots, 2.8%) and *H. prostrata* (n = 14 plots, 3.3%). In contrast, feeding residues within rehabilitation plots were frequently observed (n = 53 of 90 plots, 58.9%), with most residues from *B. squarrosa* and *H. undulata.* This difference may relate in part to differences in the prevalence of these plant species within native forest plots, c.f. *B. sessilis* was present in 112 plots (26.4%) vs. only 5 plots (1.2%) for *B. squarrosa,* while *H. prostrata* was present in 45 plots (10.6%) vs. 23 (5.4%) for *H. undulata*. Overall, the presence and stem density of proteaceous shrubs was far higher in rehabilitation plots than in native vegetation plots, with some form of common proteaceous food plant present in nearly all rehabilitation plots.

Potential Nest Hollows

Ground-based observations identified 59 potential hollow-bearing trees within 57 sampling plots within native forest and remnant (paddock) vegetation (13.4% of plots; n = 500 plots overall), including 53 potential hollow-bearing trees within 51 plots in native forest (12.0% of native forest plots; n = 425 plots).

Finn et al. (2011) estimated the proportions of potential black-cockatoo hollows observed in Jarrah, Marri, and Wandoo during ground-based surveys that were actually 'large' hollows (based on post-felling inspection of observed hollows). They found that only 31.5% of potential black-cockatoo hollows observed in Jarrah were actually 'large' hollows and therefore potentially suitable for nesting (not considering other factors influencing hollow suitability, e.g. specific interior dimensions, aspect and height of hollow, or occupancy by other species). In contrast, more than half of the potential black-cockatoo hollows observed in Marri (55.6%) and Wandoo (66.7%) were 'large' hollows. These are estimates of 'large' hollows; these hollows may not be suitable cavities for nesting for several reasons, thus the actual density of potential is likely to be smaller than these estimates.

Application of these proportions to the results from this study provides these estimates of hollow prevalence (assuming 1 hollow per tree) of 37.9 Jarrah 'hollow' per km^2, 27.2 Marri 'hollows' per km^2, and 17.6 Wandoo 'hollows' per km^2. These frequencies are similar to those observed in Biggs (2008), with the exception of Marri, which was higher in this study.

These densities should be viewed with great care, given the caveats above and the additional caveats that: (a) black-cockatoos appear to only rarely nest within Jarrah within the Jarrah-Marri forest (R. Johnstone, WA Museum, personal communication), and (b) nest-site suitability is almost certainly linked to food availability and the presence of a nearby (<2 km distant) permanent water source. These factors likely mean that nesting activity is largely restricted to suitable Marri and Wandoo hollows located near sumps, swamps, and farm dams.

Statement of Habitat Values for the Acquired Lands

This study demonstrates that the eastern acquired lands provide feeding habitat for all three black-cockatoo species, as well as breeding habitat for Carnaby's Cockatoos and FRTBC. While the relative value of these habitats is difficult to determine, the overall value of the area is enhanced by: (a) the proximity of food sources in the Sotico pine plantation and in mine-site rehabilitation areas and (b) the presence of water sources within NBG tenements and the farmlands to the east.

FRTBC: As FRTBC may breed throughout the year and breeding effort is known to vary greatly from year to year, it is difficult to estimate how many pairs are likely to breed within the acquired lands. However, the local FRTBC population associated with the eastern acquired lands and adjacent areas is unlikely to exceed 150-250 birds, based on sightings and group sizes.

Carnaby's Cockatoos: Carnaby's Cockatoos have a more defined breeding season, and while abundance is also difficult to measure, observed nesting rates and observations of breeding/nesting behaviour (e.g. single birds flying to/from a water site) suggest that eastern acquired lands could contain between 20 – 50 breeding pairs, with the number breeding varying from year to year.

The eastern acquired lands have experienced a different forest management regime (e.g. logging intensity, prescribed burning regime, retention of felled and fallen logs) than adjacent State Forest habitats, and so differences may occur in the availability of food and potential nest hollows. This area also lies within the ecotone transitioning between Jarrah-Marri forest and Wandoo woodland, which creates differences in (e.g.) the presence and productivity of food plants along an east-west gradient.

2. INTRODUCTION

2.1 Conservation Status

In 2009 Forest Red-tailed Black-Cockatoos (*Calyptorhynchus banksii naso*) [FRTBC] were listed as Vulnerable under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*. As a result of this listing, three nationally threatened black-cockatoos now occur in the Jarrah-Marri forest of Western Australia: FRTBC (a subspecies), Carnaby's Cockatoos (*Calyptorhynchus latirostris*), and Baudin's Cockatoos (*Calyptorhynchus baudinii*). All three are also listed as Schedule 1 fauna [species that are 'rare or likely to become extinct and in need of special protection'] under the Western Australia *Wildlife Conservation Act 1950*.

2.2 Conservation Concerns in the Jarrah-Marri Forest

The Newmont Boddington Gold (NBG) mine is located within the Jarrah-Marri forest in southwestern Australia. Loss of breeding and feeding habitat within the Jarrah-Marri forest through logging and mining has been identified as a conservation concern for black-cockatoos, both in recovery planning (Chapman 2005) and in the scientific literature (e.g. Mawson and Long 1994; Calver and Dell 1998 a,b; Abbott 1999; Abbott and Whitford 2002; Wardell-Johnson et al. 2004; Garnett et al. 2011).

Black-cockatoos are among the more vulnerable of hollow-dependent fauna because they nest in large hollows occurring only in mature and senescent trees that are more than 150 years old (Whitford 2002, Whitford and Williams 2002, Whitford and Stoneman 2004). FRTBC and Carnaby's Cockatoos breed throughout the Jarrah-Marri forest, while Baudin's Cockatoos breed in southern sections of the Jarrah-Marri forest (Saunders and Ingram 1995, Johnstone and Storr 1998, Johnstone and Kirkby 2008; T. Kirkby, WA Museum, personal communication).

All three species use the Jarrah-Marri forest for feeding, either year-round, seasonally, or during seasonal migrations (Saunders 1974a, 1980; Johnstone and Kirkby 1999, 2008). Recent research has indicated that restored vegetation at mine sites in the Jarrah-Marri forest can provide feeding habitat for black-cockatoos, although the value of this food source relative to native forest has not been determined (Lee et al. 2010, Doherty 2010, Wingfield 2010).

2.3 Black-cockatoos at NBG

All three black-cockatoo species occur at NBG, based on long-term study from 2007-2010 (Lee et al. 2010; Biggs et al. 2011; Finn 2011). While Carnaby's Cockatoos and FRTBC are present year-round at NBG in small numbers, larger abundances of Carnaby's Cockatoos also occur as flocks of this species migrate between Wheatbelt breeding sites and feeding areas on the Swan Coastal Plain. Baudin's Cockatoos peak in abundance from April-September. Nest sites for Carnaby's Cockatoos and FRTBC occur within or near to NBG (Finn 2011; this study). NBG is considered outside the breeding range of Baudin's Cockatoos, with the species breeding in the Karri forest and southern Jarrah-Marri forest from spring-autumn (Johnstone and Kirkby 2008). However, there are indications that the breeding range of this species may be shifting (T. Kirkby, WA Museum, personal communication).

Studies of crop contents and observations of feeding behaviour indicate that two eucalypt species (Jarrah *Eucalyptus marginata* and Marri *Corymbia callophylla*) are the main food sources for black-cockatoos in the forests of southwestern Australia (Saunders 1974a, 1980; Johnstone and Kirkby 1999, 2008). This association reflects both the energetic characteristics of Jarrah and Marri fruits and the fact that these two eucalypts are the

dominant over-storey species across the extent of the Jarrah-Marri forest, occurring at a ratio of between 2:1 to 9:1 depending on location, slope position and silvicultural practices (Pryor 1959, Abbott and Loneragan 1986, Whitford 2002, Koch and Samsa 2007).

Baudin's Cockatoos are often considered Marri specialists, although they also eat proteaceous shrubs, insect larvae, orchard fruit, and other plants, including the buds and flowers of *Banksia* spp. and *Eucalyptus* spp. (Saunders 1974b; Johnstone and Storr 1998; Cale 2003; Chapman 2007b; Johnstone and Kirkby 2008). Marri and Jarrah seeds comprise around 90% of the diet of FRTBC, although they also feeds on the seeds of other eucalypts, as well as those of Sheoak *Allocasuarina fraseriana* and Snottygobble *Persoonia longifolia* (Robinson 1960; Johnstone and Storr 1998; Johnstone and Kirby 1999; Cooper et al. 2003). Research by the WA Museum suggests that the foraging ecology of FRTBC had changed over the past 12 years, including changes in the proportions of different food plants (Ron Johnstone and Tony Kirkby, WA Museum, unpublished data). Carnaby's Cockatoos also feed within forested areas, but generally have a more varied diet, including seeds, flowers, and nectar of Jarrah, Marri, *Banksia* spp., *Hakea* spp., and *Pinus* spp., with these food plants occurring within proteaceous scrubs and heathland, eucalypt forests and woodlands, and pine plantations (Saunders 1974a,b; Saunders 1980). All three species will feed on mine-site revegetation (Lee et al. 2010, Doherty 2011, Wingfield 2011).

Lee et al. (2010) studied the feeding activity of black-cockatoos within mine-site rehabilitation areas at NBG. They found that feeding residues from proteaceous shrubs were present in 53 of 90 (58.9%) plots. Marri feeding residues were also common, with residues bearing markings indicative of feeding by Baudin's Cockatoos present in 27 plots (30%); Marri feeding residues with markings indicative of feeding by FRTBC were present in six plots (6.7%). Of the proteaceous shrubs, most stems with feeding residues (n = 172) were from two species: *Banksia squarrosa* (n = 110 stems, 64%) and *Hakea undulata* (n = 45 stems, 26%). BBC fed on 54 Marri stems and FRTBC on 8 Marri stems. No Jarrah feeding residues were observed.

2.4 Habitat Values for Black-Cockatoos

Habitat value refers to both breeding habitat (i.e. the provision of resources, conditions, and other factors necessary to support breeding) and feeding habitat (i.e. the availability of plant food sources). The quality of breeding habitat is likely to reflect: (a) the availability of suitable nest hollows (within mature or senescent eucalypts); (b) the proximity of these hollows to food sources and a reliable water source; and (c) adequate food availability throughout the breeding period.

Food availability for black-cockatoos is a function of the diversity, abundance, distribution, energetic & nutritional qualities, and seasonality (phenology) of the food sources within a particular area. The physiology of black-cockatoos obligates them to daily water intake, so the presence of reliable water sources is also an important ecological requirement, particularly during the summer months when natural waterbodies such as streams, wetlands, and puddles may be dry.

While it may be easier to define the value of breeding habitat based on characteristics that are readily-quantifiable (e.g. abundance of potential nest hollows), an effective assessment should consider other factors that less amenable to quantification or which require a more rigorous approach to gather data for, such as occupancy of nest hollows by competitor species, year-round presence of water sources, and food availability within a short distance from the nest site, the latter factor representing a critical determinant of breeding success (Saunders 1977). Similarly, the

habitat value of a particular area should also be considered in the context of the larger landscape matrix to which it belongs. In other words, habitat values should not be viewed in isolation, but in association with other habitats occurring around it.

2.5 Study Objectives

The overall aim of this study was to assess the value of the eastern acquired lands for black-cockatoos, in terms of the quality of the feeding and breeding habitat that this area provides.

The specific objectives for the study were to:

1. Describe general patterns of species occurrence, distribution, and breeding activity within the acquired lands, based on sightings of black-cockatoos and observations of feeding residues.

2. Establish a list of food plant species for black-cockatoos at NBG, based on behavioural observations and feeding residues, and describe the general availability of these food sources within the acquired lands.

3. Compare black-cockatoo feeding activity across four different land uses: (a) native forest, (b) mine-site rehabilitation, (c) remnant vegetation within a livestock paddock, and (d) pine plantation, based on frequencies of feeding residues within vegetation sampling plots.

4. Examine the abundance of potentially-suitable nest hollows with the acquired lands, based on counts of potential hollow-bearing trees from ground-based surveys and extrapolation of these counts to a landscape-scale.

3. METHODS

3.1 Study Area

Landscape Description

The study area contained three landscape elements: (a) mining tenements for Newmont Boddington Gold (NBG); (b) an area of land to the east of the NBG site that purchased Sotico Pty Ltd in 2009 (the 'eastern acquired lands'); and (c) two resource production landscapes adjacent to NBG: Alcoa Hotham Farms and the Sotico Boddington pine-blue gum plantation[1] (Figure 1).

The acquired lands were the focus for the study. However, some research was also conducted within the other landscape elements present in order to improve out understanding of how black-cockatoos using the broader landscape matrix around NBG and the acquired lands, which includes native forest, pasture, softwood plantation, and livestock pasture. NBG is bordered to the west and north by native forest (State Forest and Monadnocks Conservation Reserve), to the south by a mix of remnant native forest, agricultural land, and mine-site rehabilitation (Alcoa Hotham Farms, Alcoa Hedges gold mine, and private landholdings, and to the east by softwood plantation, agricultural land, and native forest (Sotico plantation, private landholdings).

General site description

The NBG mine lies between the 700mm and 800mm isohyets on the eastern boundary of the northern Jarrah forest subregion on highly leached soils of the Darling Plateau (Dell et al. 1989, Rayner et al. 1996), near the ecotone along the eastern margin of the Jarrah forest shifting towards Wandoo woodland further east. Native vegetation around NBG is mainly open eucalypt forest, with the upper-storey dominated by Jarrah interspersed with varying admixtures of Marri and Wandoo *Eucalyptus wandoo*; a middle-storey sometimes comprised of Bull Banksia (*Banksia grandis*) and Sheoak (*Allocasuarina fraseriana*); and a shrub layer of proteaceous and other shrubs (Dell et al. 1989). Sandy soils along upper slopes are associated with the presence of Sheoak and moist, fertile soils with Marri (Worsley Alumina Pty Ltd. 1999). The site was first logged in the early 1900s and has been logged at least twice since (Heberle 1997). Gold-mining operations began at NBG in 1987 (Rayner et al. 1996).

Rehabilitation Areas

Rehabilitation areas (n = 24) at NBG cover 190 ha (in total), and were established between 1998-2002 using rehabilitation protocols similar to those at other mine sites in the region (see overview in Koch 2007). Plant species used occur in the surrounding forest, with mid-storey and shrub species including Sheoak (*Allocasuarina fraseriana*) and proteaceous shrubs (*Banksia* and *Hakea* spp.), and canopy-forming species including Jarrah, Marri, and Wandoo (*E. wandoo*). Most rehabilitation areas at NBG have a well-developed layer of proteaceous shrubs with interspersed regenerating Jarrah and Marri stems of a height (5-12 m) and stem diameter that makes them sufficiently robust to support individuals of all three black-cockatoo species.

3.2 Study Design & Duration

[1] Hotham Farms is an Alcoa Farmland agricultural holding managed for pasture and livestock production. The Sotico plantation is owned by Bunnings Forest Products Pty Ltd, trading as Sotico Forest Products.

The study had two research components: (a) vehicle-based surveys for black-cockatoos (*black-cockatoo surveys*) and (b) quadrat ('plot') sampling to collect information on feeding residues, vegetation characteristics, and other environmental factors (*plot sampling*). Vehicle-based surveys of the study area were conducted once a month from October to March 2010. Plot sampling was conducted in October 2009 and from December 2009 – March 2010, except for mine-site rehabilitation areas, which were sampled in winter 2009.[2]

3.3 Black-cockatoo Surveys

Vehicle-based surveys were begun at first light and continued to mid-morning. The survey route included the passable roads within the study area. If black-cockatoos were heard, the species, time, and general location were recorded. If black-cockatoos were observed, a formal black-cockatoo sighting protocol was followed, which included recording of species, time, GPS position, activity, and group size.

3.4 Plot Sampling

Distribution of plots

This study examined variation in feeding activity across a landscape consisting of: (a) multiple land uses and (b) a range of topographic positions. The 'land use' aspect of the study considered the four major land uses occurring in the landscape within and adjacent to NBG tenements and the eastern acquired lands[3]: native forest, mine-site rehabilitation, remnant vegetation within a livestock paddock, and pine plantation. The 'topographic' aspect of the study considered a range of landscape positions: gully/valley floor, lower slope, mid-slope, upper slope, hill/ridge-top.

Native forest

Seventeen 1 km x 1 km **sample sites** were positioned within NBG tenements (n = 4), the eastern acquired lands (n = 12 grids), and State Forest (n = 1) (Figure XX). Each sample site was orthogonally gridded at 200m intervals with a 25 m x 25 m (0.625 ha) **sample plots** situated at each grid intersection, giving n = 25 sample plots per sample site and an overall sample size of n = 425 Native Forest plots for the study (Figure XX). Sample sites were positioned using a topographic map, with the sample sites situated so as to contain the full range of topographic positions (i.e. gully/valley floor through to hilltop/ridgeline). Gridlines ran north-south and east-west.

Remnant vegetation (paddock)

Three 1 km x 1 km samples sites were positioned within the northeast corner of Alcoa Hotham Farms. The grid layout, method for positioning sample sites, and sample plot dimensions (0.625 ha) were the same as for native forest sample sites, with the exception that only paddock areas containing stands of native vegetation were considered. As each Remnant Vegetation sample site contained 25 sample plots, the overall sample size of Remnant Vegetation sample plots was n = 75.

Remnant vegetation within paddocks occurs included wetland vegetation, single eucalypt stems, small stands of eucalypts, and patches of contiguous eucalypt forest or woodland up to about 50 ha.[4] Where no remnant vegetation

2 Sampling of plots within mine-site rehabilitation areas also occurred in summer 2009/10 and winter 2010, but these results are not considered here as the frequencies of residues are similar in the two later sampling periods.

3 We did not active mining areas and associated infrastructure.

4 We did not consider paddock grass as vegetation.

was present at a sample plot (i.e. at an intersection of the orthogonal grid), we recorded a score of 'no vegetation present' as well as the topographic position. We then shifted the location of the plot to a 'nearest neighbour' plots by identifying the nearest patch of remnant vegetation and recording the distance and compass direction (azimuth) to the closest piece of vegetation in this patch. Nearest neighbour plots were positioned by walking directly from centre of the grid intersection sample plot to the outer edge of the remnant vegetation (or single tree stem, in some cases). One edge of the plot was positioned perpendicular to this point; the sampler then continued walking in the same direction (i.e. along the same azimuth from the centre of grid intersection sample plot) for 25m, where the other edge of the plot was positioned (again along a line perpendicular to this point). We sampled n = 30 nearest neighbour plots (i.e. n = 105 total plots, n = 75 with vegetation present).

Pine plantation

One 1 km x 1 km sample site with 25 plots was positioned within an area of Sotico pine plantation just north of the acquired lands (Figure XX). Plots were 0.625 ha (25 m x 25 m). No vegetation characteristics were recorded; however, an estimate of stand density was determined.[5]

Mine-site rehabilitation

We sampled within nine mine-site rehabilitation areas at NBG, with each area containing five interior (>25m from any edge) plots and five exterior plots (n = 90 total plots). Plot sizes were 0.1 ha: and measured 10 m × 10 m for interior plots and 5 m x 20 m for exterior plots. All plots are separated by ≥75 m. The smaller plot sizes were used because the density of vegetation made the sampling of larger (i.e. 0.625 ha) plots impractical.

Data recorded for plots

For each plot, we collected data on vegetation composition, structure, and phenological status, and on the presence/absence and characteristics of black-cockatoo feeding residues. Table AA-CC describes the environmental, vegetation, feeding residue, and potential nest hollow data collected during plot sampling. For Marri stems, 1.5 m was identified as the minimum height at which Marri stems can first bear fruit within native forest habitats.

Feeding residues

Different species of black-cockatoos leave characteristic markings on the plant residues left behind after feeding (Johnstone and Kirkby 1999, Cooper et al. 2003, Weerheim 2008). Feeding residues vary by plant species, but include branches, seed husks, flowers, and eucalypt fruits that are broken, cracked open, or show distinctive signs of manipulation by black-cockatoos. For some plants species, it is possible to determine the black-cockatoo species leaving the residue, either by the plant species fed upon (e.g. only FRTBC typically feed on Sheoak) or characteristics of the feeding trace. For example, FRTBC shear Marri fruits at angle ('bottomslice'), while Baudin's Cockatoos pry seeds out, leaving the fruit intact ('lever') (Figure XX). However, Carnaby's Cockatoos may use both techniques with some modification (e.g. in handling and processing of the fruit), and generally on green fruits that are soft enough for the beaks of Carnaby's Cockatoos to manipulate.

We recorded whether feeding residues were likely to be 'young' (i.e. fed upon within the last year) or 'old' (>1 year-old), based on their colour (e.g. grey, faded indicates 'old' residues) and condition (e.g. deteriorated indicates

[5] Age of these pine stands needs to be determined.

'old' residues). In most cases, these residues can be considered generally indicative of a particular black-cockatoo species, with the caveat that full certainty is not possible. In the future, a morphometric analysis might be able to definitively describe differences between species and the variation within species.

For some food plants, field identification of residues is generally not possible without observation of birds feeding on them, e.g. Couch Honeypot (*Banksia dallanneyi*) (a small proteaceous shrub that grows close to the ground). Likewise, the flower spikes of Bull Banksia (*Banksia grandis*), once severed from their stem, tend to lose their color within a few weeks, making it difficult to determine whether the flower spikes fell because of the feeding activity of black-cockatoos or because the plant shed them once the flowering stage was complete.

Habitat type

Habitat types were categorised as *primary* or *secondary* (Table DD). Primary habitat types were classified based on stem densities for canopy-forming tree species. For the purposes of this study, only certain eucalypts (Jarrah, Marri, Wandoo, Yarri, or *Eucalyptus rudis*) and Sheoak (*Allocasuarina fraseriana*) were considered as canopy-forming tree species. Stems were defined as stems of these species that were $\geq$1.5 m in height. Primary habitat types were defined in terms of the dominant tree species, which was defined as the tree species with the highest stem density; they were defined as an 'admixture' if the dominant tree species accounted for <80% of stems within the plot. Secondary habitat types were also defined, either to indicate the presence of a high density of potential food plants or an unusual feature of the vegetation.

Identification of potential hollows

Table CC gives the data recorded for potential nest hollows. Identification of potential hollows was based on published descriptions of black-cockatoo nest hollows in south-western Australia (Saunders et al. 1982, Mawson and Long 1994, Johnstone and Storr 1998). Potential nest hollows were identified during ground-based surveys according these criteria: (a) an opening at least horizontal relative to the ground surface (i.e. not opening downwards); (b) an entrance appearing $\geq$12cm across; and (c) space for a hollow interior of $\geq$25cm (i.e. with the trunk or branch in which the hollow occurs). Personnel also considered indicators of senescence, decay, fire, and storm damage, such as decaying wood structure, dead branches, and dead wood below the assumed hollow entrance, and the presence of chew marks (because used nest hollows are generally chewed around the entrance).

Trees identified as bearing potential hollows were scored on several criteria developed by Whitford and Stoneman (2002) in their study of predictors for the presence of hollows in Marri and Jarrah trees in the Jarrah forest: presence/absence of a fire scar (categorical, Crown Senescence (ordinal scale), Dead Branch Order (ordinal scale), Crown Lost (ordinal scale), and percentage of Crown Dead (percentage).

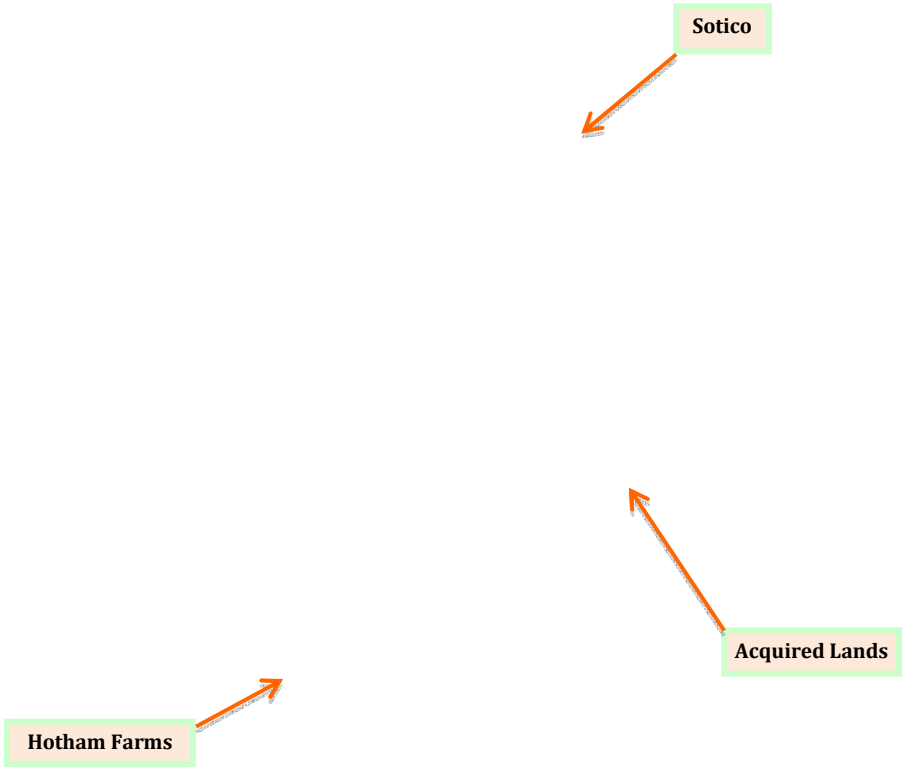

Figure 1: Map of Study Area

This figure shows the extent of the study area for this project. All sample sites were located within the areas outlines in yellow. Also shown are the general locations for the four major land tenures: (a) NBG tenements; (b) Alcoa Hotham Farms (livestock paddocks); (c) eastern acquired lands; and (d) Sotico pine & blue-gum plantation. Mine-site rehabilitation areas sampled in support of this study are located within NBG tenements.

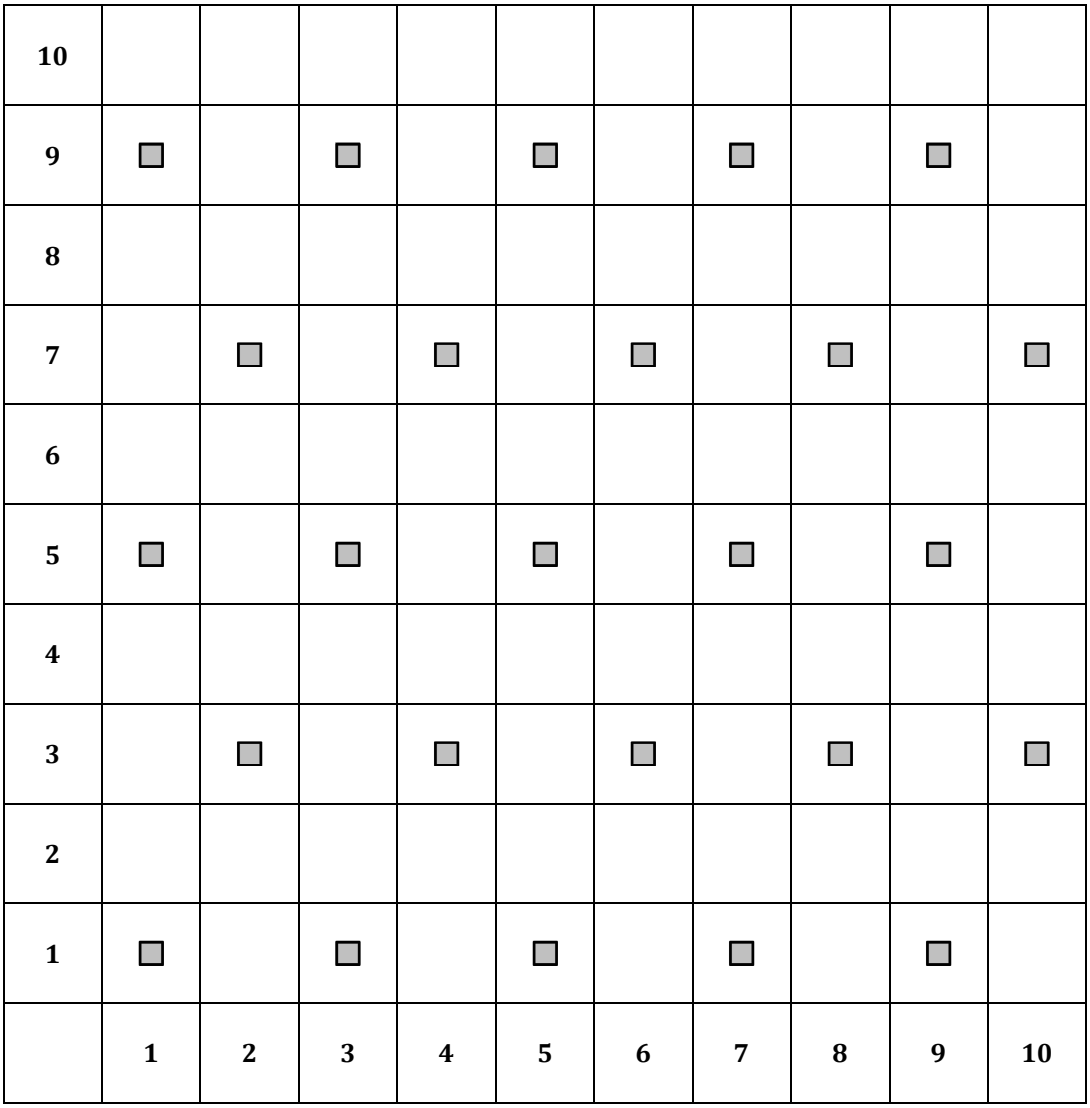

Figure 2: Design of Sample Sites

This figure shows the orthogonal grid design of the sample sites with Native Forest, Paddock (remnant vegetation), and Pine areas. The sample sites measure 1000 m x 1000 m (1 km^2) and each contain n = 25 sample plots at systematic intervals. A grey square (☐) shows the location of a 25 m x 25 m (0.625 ha) sample plot.

Table AA: Data collected from plots in native forest and remnant vegetation

A. General	
Measurement	**Description**
Sample Site	1 km x 1 km grid to which the plot belongs
Land Use	Native Forest or Remnant Vegetation
Landscape Position	Topographic Position: gully/valley floor, lower slope, mid-slope, upper slope, hill/ridge-top
Primary Habitat Type	Primary Habitat Type *see Table XX for descriptions*
Secondary Habitat Type	Secondary Habitat Type (where applicable) *see Table XX for descriptions*
DBH of 3 largest Marri stems	Diameter-at-Breast-Height of three largest Marri stems
No. of Marri stems	Number of Marri stems ≥1.5 m high
Presence of Food Plants and/or Indicator Species	Presence or absence of these species: Jarrah (*Eucalyptus marginata*) Marri (*Corymbia calophylla*) Wandoo (*E. wandoo*) Yarri/Blackbutt (*E. patens*) Sheoak (*Allocasuarina fraseriana*) Couch Honeypot (*Banksia dallanneyi*) Bull Banksia (*Banksia grandis*) Parrot Bush (*Banksia sessilis*) Pingle (*Banksia squarrosa*) Honeybush (*Hakea lissocarpha*) Harsh Hakea (*Hakea prostrata*) Wavy-leaved Hakea (*Hakea undulata*) Snottygobble (*Persoonia longifolia*) Glowing Wattle (*Acacia celastrifolia*) These species were chosen because they: (a) comprise the major known food plants for black-cockatoos at NBG; (b) represent important structural components of certain Jarrah forest habitats; and/or (c) may represent useful indicator species for black-cockatoo feeding activity or the presence/absence of potential hollows.
Presence of Bee Hive	Presence or absence of a bee hive
B. Potential Hollows	
Measurement	**Description**
Presence of Potential Hollow	Presence or absence of a potentially suitable hollow *see Section 3.4 for a description of criteria for a potential hollow*
Number of Trees Bearing Potential Hollows	Number of trees in which a potentially suitable hollow occurs

Table AA (cont.)**:** Data collected from plots in native forest and remnant vegetation

C. Eucalypt and Sheoak Feeding Residues Jarrah, Marri, Yarri, Sheoak	
Measurement	**Description**
Presence of Feeding Residues	Presence or absence of feeding residues (husks) from trees bearing signs of feeding activity from black-cockatoos *see Section 3.4 for a description of feeding residues*
Presence of Feed Trees	Presence or absence of a tree with feeding residues present
Number of Feed Trees	Number of trees with feeding residues present
Feeding Residues: *Abundance*	Number of husks present within the plot possessing signs of black-cockatoo feeding activity on them * If husks were classified as OLD (see below) they were not counted. * An estimate was sometimes recorded.
Feeding Residues: *Intensity*	Categorical measure for number of husks present: 1 = <20 2 = 20- 99 3 = 100-499 4 = 500-999 5 = >1000
Feeding Residues: *Age*	Age of feeding residues present in plot based on colour & condition OLD = (older than 1 year) (grey, degraded) YOUNG = (within last 12 months) (not grey)
Feeding Residues: *Black-cockatoo Species*	Black-cockatoo species leaving feeding residues >1 species in some cases; cannot be determined in others

D. Proteaceous Feeding Residues *Banksia* species: *Banksia sessilis, B. squarrosa* *Hakea* species: *Hakea undulata*, *H. prostrata*, *H. varia*	
Measurement	**Description**
Stems (*Hakea* only)	Number of stems with feeding residues
Branches (*Banksia* & *Hakea*)	Number of branches with signs of feeding activity
Fruit casing (*Hakea* only)	Number of split seed casings on the ground beneath the stem

Table BB: Data collected for feed trees (eucalypts & Sheoak) and proteaceous feed stems

A. Plot Descriptors	
Measurement	**Description**
Sample Site	1 km x 1 km grid to which the plot belongs
Land Use	Native Forest or Remnant Vegetation
Landscape Position	Topographic Position: gully/valley floor, lower slope, mid-slope, upper slope, hill/ridge-top
Primary Habitat Type	Primary Habitat Type *see Table XX for descriptions*
Secondary Habitat Type	Secondary Habitat Type (where applicable) *see Table XX for descriptions*
B. Tree & Residue Descriptors	
Measurement	**Description**
Species	Food plant species
Presence of Other Feed Trees (eucalypts & Sheoak only)	Presence of other feed trees within the plot
DBH (cm) (eucalypts & Sheoak only)	Diameter-at-breast-height (1.3 m)
Multiple Stems Fed Upon (proteaceous shrubs)	Presence or absence of ≥1 stem with evidence of feeding activity
Stem Height (proteaceous shrubs)	For proteaceous shrubs: height of stem
Green Husks (Marri)	Green fruits present on tree
Phenological Status	Phenological status of tree or shrub(s)
Multiple Species Feeding	Presence of feeding residues from ≥1 black-cockatoo species
Black-Cockatoo Species	Black-Cockatoo species leaving the feeding residues If this can be definitively determined; >1 species in some cases
Age	Age of feeding residues based on colour & condition OLD = (older than 1 year) (grey, degraded) YOUNG = (within last 12 months) (not grey)
Number of Residues	Number of feeding residues (husks, branches, split seed casings)
Intensity	Categorical measure for number of husks present: 1 = <20; 2 = 20- 99; 3 = 100-499; 4 = 500-999; 5 = >1000 No intensity for proteaceous: branches, stems, fruit casings
Multiple Feeding Events	Presence of feeding residues of different ages Suggesting ≥1 feeding event.

Table CC: Data collected for potential hollows

A. Plot Descriptors	
Measurement	**Description**
Sample Site	1 km x 1 km grid to which the plot belongs
Land Use	Native Forest or Remnant Vegetation
Landscape Position	Topographic Position: gully/valley floor, lower slope, mid-slope, upper slope, hill/ridge-top
Primary Habitat Type	Primary Habitat Type *see Table XX for descriptions*

B. Tree & Hollow Descriptors	
Measurement	**Description**
Species	Tree species
DBH (cm)	Diameter-at-breast-height (1.3m) in cm Record if stem has hollow butt.
Stag	Whether tree is a stag or not
Hollow Location	Location of hollow within the host tree: trunk (central stem), tube (entire stem is cavity with hollow opening to top), branch
Presence of Bees	0 = not present in the tree; 1 = present in the tree
Hollow Size	1 = 10-20 cm; 2 = >20 cm if >1 hollow, then size of largest
Hollow Butt	0 = not present; 1 = present
Hollow-Used	Evidence of use of hollow Based on evidence of chewing around the hollow entrance or observation of an animal appearing when base of tree is 'knocked'.
Fire-scar	Presence or absence of a fire scar at the base of the tree
Crown Senescence	An ordinal assessment of the stage of crown decline *See Table XX* ; Following Whitford 2001 and Whitford and Williams 2002
Dead Branch Order	An ordinal assessment of the terminal order of the largest of dead branches within the tree crown *See Table XX* ; Following Whitford 2001 and Whitford and Williams 2002
Crown Lost	An assessment of the amount of crown decline Assessed as the proportion of the original live crown lost from the tree 1: 0-40% of the crown missing 2: 41-65% of the crown missing 3: 66-80% of the crown missing 4: 81-95% of the crown missing 5: 96-100% of the crown missing Following Whitford 2001 and Whitford and Williams 2002
Crown Dead	An estimate of the proportion of crown volume that consisted of dead wood Following Whitford 2001 and Whitford and Williams 2002

Table DD: Primary and secondary habitat types defined for the this study

A 'stem' refers to a stem of canopy-forming tree species (eucalypts or sheoaks for this study).

Primary Habitat Types	
Habitat Type	**Description**
1. Jarrah	Jarrah >80% of stems
2. Jarrah-Marri	Jarrah with Marri >20 and <50% of stems
3. Jarrah-Sheoak	Jarrah with Sheaok >20 and <50% of stems
4. Jarrah-Wandoo	Jarrah with Sheaok >20 and <50% of stems
5. Jarrah Mixed	Jarrah with >20% combination of other tree species
6. Marri Dominant	Marri with other tree species >20 and < 50% of stems
7. Sheoak/ Sheoak Dominant	Sheoak >80% of stems or with Jarrah >20 and <50% of stems
8. Wandoo Dominant	Wandoo with other tree species >20 and < 50% of stems
9. Wandoo	Wandoo >80% of stems
10. Other	e.g. Yarri, *Melaleuca* sp., swamp, modified land, mixed
Secondary Habitat Types	
1. Dryandra Thicket	≥20 stems of *Banksia sessilis*
2. Wattle Thicket	≥20 stems of *Acacia celastrifolia*
3. Other	e.g. *Melaleuca* spp., *E. rudis*, swamp, granite outcrop

4. RESULTS

A. Black-Cockatoo Sightings

4.1 Sightings within acquired lands

Overall patterns

All three black-cockatoo species were observed during the course of the study, with Carnaby's Cockatoos and FRTBC accounting for most sightings (Appendix 1). While black-cockatoos were observed throughout the acquired lands, the highest concentration of sightings was along the eastern margin in the vicinity of Boundary Road and the paddocks and farm dams to the east (Figure XX).

Group size

The numbers of black-cockatoos varied from male-female pairs and family units (adult pair and one-two offspring)[6] to small flocks (<10 individuals) with the largest assemblages consisting of 20-35 birds. Most observations were of <10 birds at a time, and is suggestive of fragmentation into small groups consistent with food sources being weakly concentrated within a landscape (i.e. food sources not occurring in concentrations able to sustain large numbers of birds).

Influence of water sources

Distance to permanent water sources is also likely to be an important factor and may partially account for the concentration of observations along the western and eastern margins of the acquired lands, areas that contain (or are close) to year-round water sources such as farm dams and sumps.

4.2 Probable black-cockatoo nest sites with acquired lands and NBG tenements

Eleven probable black-cockatoo nest hollows have been identified within NBG tenements and the acquired lands (Figure XX, Table OO). Of these, ten were identified through behavioural observations, in which black-cockatoos were located (either by vocalisation or by sight), followed (in some cases), and then observed occupying a nest hollow. Occupancy was often determined using 'tree-knocking' (i.e. knocking at the base of trees, which leads nesting birds to investigate). Four of the nests were in the acquired lands.

B. Food Plants

4.3 Inventory of food plant species at NBG

The three black-cockatoo species have a wide range of known food plants, many of which have been identified at NBG during previous flora surveys (Table PP).[7]

Presence of food plants

6 With FRTBC in particular, two offspring may often be present—a dependent chick and an older, independent juvenile.

7 The list of known food plants for the three black-cockatoo species in Table PP is based on reports in the scientific and grey literature and observations of black-cockatoos feeding at NBG. The table also indicates which food plants are present at NBG (and surrounds) based on vegetation surveys.

Previous flora surveys have recorded the presence of least 30 known food plants for black-cockatoos within NBG tenements and the eastern acquired lands (Table PP). These food plants include four eucalypts, seven *Banksia* species, and ten *Hakea* species. However, most of these food sources are ephemeral (e.g. flowering/seeding for brief periods) and/or occur only in small abundances and thus represent only incidental or short-term food resources. Observations of feeding and/or feeding residues have been recorded for sixteen native plant species at NBG within native forest (n = 11 species) and mine-site rehabilitation (n = 12 species) habitats (Table EE). Feeding on pine (*Pinus radiata*) was also observed within the Sotico plantation.

Lack of feeding residues for commonly observed plants

We did not identify feeding residues for two food plant species that were frequently observed within Native Forest sample plots, or observe black-cockatoos feeding on this species (from 2007-current). Snottygobble (*Persoonia longifolia*) was present in 92 of 425 (21.6%) of Native Forest sample plots and is a known food plant for FRTBC (and the white-tailed species); however, we did not observe birds feeding on this species or any identifiable feeding residues under stems of this species. Snottygobble stems were not observed in any Paddock sample plots. *Hakea lissocarpha* was present in 285 of 392 (72.7%) Native Forest sample plots and 5 of 75 (6.7%) Paddock sample plots; however, no feeding residues were observed for this species, nor were birds observed feeding on it.

We also did not identify feeding residues for two food plant species that were frequently observed within Native Forest sample plots, but for which we have multiple observations of Carnaby's Cockatoos feeding upon. Couch Honeypot (*Banksia dallaneyi*) was present in 344 of 425 (80.9%) Native Forest sample plots and 1 of 75 (6.7%) Paddock sample plots; no feeding residues were observed but we did observe Carnaby's Cockatoos feeding on the plant. Bull Banksia (*Banksia grandis*) was present in 94 of 425 (22.1%) of Native Forest sample plots and 5 of 75 (6.7%) Paddock sample plots; no feeding residues were observed but we did observe Carnaby's Cockatoos feeding on the plant.

Feeding residues within rehabilitation areas

Within NBG rehabilitation areas, proteaceous feeding residues were most commonly observed for three species: *Banksia squarrosa*, *Hakea undulata*, and *H. prostrata*. Other species for which feeding residues were observed less frequently were: *B. sessilis*, *Hakea trifurcata, H. varia, H. cyclocarpa*, *H. incrassta*, and *H. amplexicaulis* (Table EE).

4.4 Frequencies of feeding residues: plant type & species

Feeding residues in Native Forest & Paddock plots

We recorded feeding residues for nine plant species during plot sampling within Native Forest and Paddock vegetation, including three eucalypts (Marri, Jarrah, and Yarri *E. patens*), two *Banksia* species (*B. sessilis* and *B. squarrosa*), and three *Hakea* species (*H. prostrata*, *H. undulata*, and *H. varia*) (Table HH). Marri was by far the most commonly observed feeding residue within Native Forest plots (n = 126 plots, 29.6% of plots), with residues from Jarrah (n = 4 plots, 1.1%), Yarri (n = 1 plot, 0.2%), and Sheoak (n = 5 plots, 1.2%) very infrequently observed.

Proteaceous feeding residues

Feeding residues from proteaceous shrubs were observed infrequently within Native Forest sample plots (n = 29 plots, 6.5%), with most residues coming from *B. sessilis* (n = 12 plots, 2.8%) and *H. prostrata* (n = 14 plots,

3.3%) (Table HH). In contrast, feeding residues within rehabilitation were most commonly from *B. squarrosa* and *H. undulata* (Lee et al. 2010). This may relate to difference in the prevalence of these species within Native Forest sample plots, c.f. *B. sessilis* was present in 112 plots (26.4%) vs. 5 plots (1.2%) for *B. squarrosa,* while *H. prostrata* was present in 45 plots (10.6%) vs. 23 (5.4%) for *H. undulata*. Residues from the 'Dryandras' (*Banksia sessilis* and *B. squarrosa*) were present in 15 of the 29 (51.7%) of Native Forest sample plots that had residues from proteaceous shrubs; residues from four *Hakea* spp. (*H. undulata, H. prostrata, H. trifurcata,* and *H. lissocarpha*) occurred in 16 (55.2%) of these plots.

Eucalypt feeding residues

Within Native Forest sample plots, eucalypt feeding residues account for nearly all of the feeding residues from canopy-forming tree species. Feeding residues from eucalypts occurred within 131 of 132 (99.2%) of the sample plots containing residues from canopy-forming tree species. Sheoak was the only non-eucalypt tree species for which feeding residues were observed within Native Forest sample plots. Sheoak residues present in 5 of 132 (3.8%) Native Forest sample plots containing residues from canopy-forming tree species. Residues from pine were not observed within Native Forest sample plots. Most eucalypt feeding residues were from Marri [*n* = 126 of 132 (95.5%) plots]; Jarrah [*n* = 4 of 132 (3.0%) plots] and Yarri [*n* = 1 of 132 (0.8%) plots].

Within Paddock (remnant vegetation) sample plots, Marri and Jarrah feeding residues were each present in 10 of the 23 (43.5%) sample plots that contained residues from canopy-forming tree species. Yarri residues were present in 5 (21.7%) of these plots. No residues from proteaceous shrubs were observed within Paddock sample plots.

4.5 Frequency of feeding residues: land uses, habitat types, & landscape positions

Land uses

The feeding activity of black-cockatoos varied across the four major land uses in the NBG area. Feeding activity (as measured by the proportion of plots containing feeding residues) was higher in the two anthropogenic habitats (plantation: *n* = 25/25 plots, 100% and rehabilitation: *n* = 62/90 plots, 68.9%) than in Native Forest (*n* = 159/425 plots, 37.4%) or Paddock sample plots (*n* = 23/75 plots, 30.7%) (Table FF). Differences in activities probably relate to the diversity, density, phenology, and nutritive/energetic value of food plants within the different land uses. Pine feeding residues were observed only in Plantation sample plots; Pine stems ('wildlings') were not observed in Native Forest or Paddock sample plots.[8]

Distribution of proteaceous feeding residues

Thirteen (44.8%) of the 29 plots containing feeding from proteaceous shrubs occurred within one sample site (Sample Site 6) (Table KK). This sample site is situated in the extreme southeast corner of the acquired lands, just north of the site access road (Old Soldiers Road North) and along the margin with the paddocks to the east. The presence of Wandoo was associated with the occurrence of *Hakea* residues. All sample plots containing residues of *Hakea undulata* (*n* = 5 sample plots) and *Hakea varia* (*n* = 3 sample plots) also contained Wandoo, while 13 of 14 (92.9%)[9] of sample plots with residues from *Hakea prostrata* also contained Wandoo and 9 of 14 (64.3%) of sample plots were in the primary habitat type Wandoo Woodland.

8 Pine stems or isolated groups of Pine stems occur sporadically in native forest along the edge of the Sotico plantation and in a small number of places within NBG tenements.

9 The exception was a sample plot dominated by Yarri (*E. patens*).

All *Banksia sessilis* residues occurred with sample plots classified as the secondary habitat type *Dryandra thicket.* Another secondary habitat type, Wattle Thicket, occurred within 30 (7.1%) of Native Forest sample plots, of which *n* = 19 (63.3%) within Sample Plot 17, which includes DEC State Forest (i.e. different forest management prescriptions than for native forest areas formerly managed by Sotico).

Other associations with habitat type and landscape position

There were no clear associations between habitat types and the presence of feeding residues, although feeding residues were present in more than half of Native Forest sample plots in which Marri was the dominant canopy-forming tree (Marri Dominant: *n* = 21 of 32 plots, 65.6%) or accounted for ≥20% of stems present (Jarrah-Marri: *n* = 37 of 70 plots, 65.6%) (Table II).

Feeding residues occurred in all landscape positions within Native Forest sample plots (Table GG). Eucalypt feeding residues were distributed relatively equally across landscape positions, while proteaceous shrubs were generally observed lower in the landscape (i.e. mid-slope to gully/valley floor) (Table GG). Nearly all Ridge/Hilltop sample plots within Native Forest and Paddock areas in which Marri stems were present also contained Marri feeding residues (*n* = 28 of 31 plots, 90.3%), with Marri feeding residues next most frequent within Lower Slope sample plots (Table HH).

4.6 Marri feeding residues: black-cockatoo species & age of residue

Black-cockatoo species

Marri residues with 'lever' markings indicative of feeding by Baudin's Cockatoos were present in 112 of 126 (88.9%) Native Forest sample plots in which Marri residues were present. Marri residues with 'bottomslice' markings indicative of feeding by FRTBC were present in 52 of 126 (41.3%) Native Forest sample plots in which Marri residues were present. In Paddock sample plots, Marri residues with 'lever' markings were present in 5 of 10 (50%) plots in which Marri residues were present, while residues with 'bottomslice' makings were present in all (10 of 10 plots). Overall, only one plot contained Marri residues that were distinctly indicative of feeding by Carnaby's Cockatoos.

Age of feeding residues

Eighty-seven of the 126 (69.0%) plots with Marri residues contained residues with 'lever' markings that were classified as 'new', indicating feeding activity by Baudin's Cockatoos within the last year. 32 of 126 plots (25.4%) plots with Marri residues contained residues with 'lever' markings that were classified as 'old', indicating feeding activity by Baudin's Cockatoos more than ~12 months ago. 14 of the 126 (11.1%) plots with Marri residues contained residues with 'bottomslice' markings that were classified as 'new', indicating feeding activity by FRTBC within the last year. 45 of 126 plots (35.7%) plots with Marri residues contained residues with 'bottomslice' markings that were classified as 'old', indicating feeding activity by FRTBC more than ~12 months ago.

Associations between species and age

41 of 126 (32.5%) plots with Marri residues contained both 'bottomslice' and 'lever' residues, indicating feeding activity by both species; this percentage does consider the age of the residues present. 12 of 126 (9.5%) plots with Marri residues contained both 'bottomslice' and 'lever' residues classified as 'new', indicating feeding activity by

both species within the last year. Five of the 10 (50%) Paddock sample plots with Marri residues contained both 'bottomslice' and 'lever' residues (also not considering the age of the residues); in only 1 (10%) of these plots were both the 'bottomslice' and 'lever' residues classified as 'new'.

Of the 126 plots with Marri feeding residues, 34 (27.0%) contained residues classified as 'new' and residues classified as 'old', indicating a series of feeding events. 26 of these 34 (76.5%) plots involved 'old' residues with 'bottomslice' markings, indicating recent feeding activity by Baudin's Cockatoos and/or FRTBC and previous (>12 months) feeding activity by FRTBC. 5 of these 34 (14.7%) plots contained 'new' and 'old' with 'lever' markings, while 1 of 34 (2.9%) contained 'new' and 'old' with 'bottomslice' markings. These results suggest that, within the last 12 months, feeding activity by Baudin's Cockatoos has been more intensive than for FRTBC. However, FRTBC feeding activity has occurred within the study area, based on the presence of older residues.

Table OO: Observations of probable black-cockatoo nests at NBG

No.	Tree	Species	1	Easting	Notes
1	Marri	Carnaby	6377444	0441937	Stag at western edge of Round Swamp; occupied in spring 2008 (check date) and 2009 (27 October 2009); not occupied 10 November 2010; flagged, need GPS location; hollow is in branch within crown
2	Marri(?)	Carnaby	6373749	0441928	Old stag, probably marri; used 2008 (present 8 October 2008); no bird present in October 2009 or 10 November 2010; flagged; south of main gate and west of Siding Road; hollow is in branch within crown
3	Wandoo	FRTBC	6378812	0439779	Small hollow is 'pocket' in main stem of medium-sized wandoo; small hollow with narrow opening; just west of track along western edge of Boomerang Swamp; female FRTBC present on 30 September 2008, no bird present in 2009; female FRTBC present on 10 November 2010; flagged
4	Marri	Carnaby	6377565	0442991	Tall marri at angle; along Twinbridge Road west of Gate 17; pair around hollow (investigating) in 2008 while we were setting up an ANH nearby; female in hollow in September/October 2009 (check date) but not present on 27 October 2009; female CBC present 10 November 2010; flagged
5	Wandoo	FRTBC	6374900	0447500	Female FRTBC in hollow with male roosting on branch (16 October 2009); not present 28 October 2009 or 25 November 2009; not present 10 November 2010; flagged; medium-sized wandoo; hollow is in main stem; just north of Roberts Road before (i.e. west of) junction with Boggy Brook Road; 87cm dbh, not a stag, fire scar present; crown senescence = 3; dead branch order = 1.5; crown lost = 1; crown dead = 23%
6	Wandoo	Carnaby	6374700	0447500	Large wandoo; pair observed copulating on this tree (16 October 2009), then female present in hollow (27 October 2009) and also present on 25 November 2009; almost directly south of Tree 6; south of Roberts Road before (i.e. west of) junction with Boggy Brook Road; no CBC in hollow on 12 January 2010; female CBC present 10 November 2010
7	Marri	Carnaby	6375693	0445479	Large marri; female observed in hollow, male on branch (27 October 2009); not present 25 November 2009; female CBC present on 11 November 2010; just north of Roberts Road just before (i.e. west of) junction with House Brook Road;
8	Wandoo	FRTBC	6372891	0449208	Wandoo about 40m from Old Soldiers Road (mine access road) to NW of mine accommodation village and just SW of sewage treatment ponds; male on branch, female in hollow (in main stem) (27 October 2009); not occupied 11 November 2010
9	Marri	Carnaby	6373724	0441597	Along gully; stag; located 29 October 2009 with female CBC; not occupied 10 November 2010
10	Jarrah	Not known	6381137	0440690	Tree cleared in 2007; in F1 RDA area; not observed by HF - is note in records that an EWP was used to determine that the tree had been used by black-cockatoos in the last year
11	Marri	Carnaby	6374425	0443060	New nest 2010; occupied by female CBC on 11 November 2010; large (169cm dbh) marri; hollow is in trunk; just NE of gate to Roberts Road from site access road (~200 north of track)

Table PP: Food plants of Baudin's Cockatoos, Carnaby's Cockatoos, and FRTBC.

This list of food plants is based on reports in the scientific and grey literature and observations at NBG and elsewhere. The list draws primarily from: Saunders (1980), Johnstone and Kirkby (1999, 2008), Valentine et al. (2008), and H. Finn (unpublished data). The presence of plant species at NBG follows the flora surveys reported in Worsley Alumina Pty Ltd. (1999) and Mattiske Consulting Pty Ltd. (2010).

Species	Part of Plant Used	Baudin	Carnaby	FRTBC	Present at NBG
Eucalypts					
Marri *Corymbia calophylla*	seeds, nectar, buds, and flowers				
Lemon-scented gum *C. citriodora*	seeds, nectar, buds and flowers				
Red Flowering Gum *C. ficifolia*	flowers				
Silver Princess (Caesia) *E.caesia caesia*	seeds				
Illyarrie (Red-Capped Gum) *E. erythrocorys*	seeds				
Tuart *E. gomphocephala*	flower				
Bushy Yate *E. lehmannii*	seeds				
Spotted Gum *E. maculata*	seeds			rare?	
Jarrah *E. marginata*	seeds, nectar, buds and flowers				
Blackbutt/Yarri *E. patens*	seeds				
Salmon Gum *E. salmonophloia*	seed				
Albany Blackbutt *E. staeri*	seeds				
Coastal Blackbutt *E. todtiana*	seed				
Wandoo *E. wandoo*	nectar, buds, and flowers				
Eucalyptus spp.	nectar, buds, and flowers				???
Other Canopy Trees					
Forest Sheoak *Allocasuarina fraseriana*	seeds				
Allocasuarina spp.	seeds				???
Rottnest Island Pine *Callitris preissii*	seeds				
River Sheoak *Casuarina cunninghamiana*	seeds				
Orange Wattle *Acacia saligna*	bark, invertebrates				
Fig tree *Ficus* spp.	fruit				
Peppermint Tree *Agonis flexuosa*	bark, invertebrates				
Banksia spp.					
Ashby's Banksia *Banksia ashbyi*	seeds				

Slender Banksia *Banksia attenuata*	seeds, flowers, invertebrates				
Banksia coccinea	flowers				
Couch Honeypot *Banksia dallanneyi* (*Dryandra lindleyana*)					
Banksia fraseri	seeds, flowers				
Bull Banksia *Banksia grandis*	seeds, nectar, buds and flowers			dead	
Holly Banksia *Banksia ilicifolia*	seeds				
Swamp Banksia *Banksia littoralis*	seeds, flowers				
Porcupine Banksia *B. lindleyana*	nectar, buds, and flowers				
Firewood Banksia *Banksia menziesii*	seeds, flowers				
Honeypot Dryandra *Banksia nivea*	seeds, flowers				
Golden Dryandra *Banksia nobilis*	seeds				
Banksia praemorsa	seeds				
Acorn Banksia *Banksia prionotes*	seeds				
Tree Banksia *Banksia prolata*	seeds				
B.quercifolia	seeds				
Shaggy Dryandra *Banksia splendida*	seeds, flowers				
Pine Banksia *Banksia tricuspis*	seeds, flowers, invertebrates				
Urchin Dryandra *Banksia undata*	seeds, flowers				
Albany Banksia *Banksia verticillata*	seeds, flowers				
Parrot Bush *Banksia sessilis*	seeds, flowers				
Pingle *Banksia squarrosa*	seeds, nectar, buds and flowers				
Hakea spp.					
Prickly Hakea *Hakea amplexicaulis*	seeds				
Hakea auriculata	seeds				
Hakea circumalata	seeds				
Shell-leaved Hakea *Hakea conchifolia*	seeds				
H. cristata	seeds				
Ramshorn *Hakea cyclocarpa*	seeds				
Hedgehog Hakea *H. erinacea*	seeds				

Sickle Hakea *Hakea falcata*	seeds				
Hakea gilbertii	seeds				
Golfball Hakea *Hakea incrassata*	seeds				
H. lasianthoides	seeds				
Pin-cushion Hakea *Hakea laurina*	seeds, flowers				
Honeybush *Hakea lissocarpha*	seeds				
H. marginata	seeds				
Grass leaf Hakea *Hakea multilineata*	seeds				
Needles and Cork *Hakea obliqua*	seeds				
Thick-leaved Hakea *Hakea pandanicarpa*	seeds				
Harsh Hakea *Hakea prostrata*	seeds				
Candle Hakea *Hakea ruscifolia*	seeds				
Hakea scoparia	seeds				
H. stenocarpa	seeds				
Furrowed Hakea *Hakea sulcata*	seeds				
Two-leaved Hakea *Hakea trifurcata*	seeds				
Wavy-leaved Hakea *Hakea undulata*	seeds			rare	
Variable-leaved Hakea *Hakea varia*	seeds				
Other Native Shrubs/Bushes					
Callistemon spp.	nectar, buds, and flowers				
Darwinia citriodora	nectar, buds, and flowers				
Prickly Toothbrush *Grevillea armigera*	seeds, flowers				
Red Tooth Brushes *Grevillea hookeriana*	seeds, flowers				
Kerosene Bush *Grevillea paniculata*	seeds				
Bottlebrush Grevillea *Grevillea paradoxa*	seeds				
Pink Poker *Grevillea petrophiloides*	seeds				
Grevillea wilsonii	seeds				
Isopogon scabriusculus	seeds				
Lambertia inermis	nectar				
Many Flowered Honeysuckle *Lambertia multiflora*	seeds, flowers				

Grass Tree *Xanthorrhoea preissii*	seeds				
Kingia australis	seeds				
Reedia spathacea	seeds				
Snottygobble *Persoonia longifolia*	seeds				
Introduced/Exotic					
Pinaster Pine *Pinus pinaster*	seeds				
Radiata Pine *Pinus radiata*	seeds, growing tips				
Canola *Brassica napus*	seeds				
Cape Lilac (White Cedar) *Melia azederach*	seeds				
Doublegee *Emex australis*	seed				
Wild Geranium/Storksbill *Erodium* spp.*	seeds				
Guildford or Onion Grass *Romulea rosea*	seed				
Hibiscus (garden variety) *Hibiscus spp.*	flower				
Jacaranda spp.	seeds				
Liquid Amber *Liquidamber styraciflua*	seeds				
Wild Radish *Raphanus raphanistrum*	seeds				
Rosewood *Tipuana tipu*	seeds				
Sunflower *Helianthus annuus*	seeds				
Umbrella Tree *Schefflera actinophylla*	fruit				
Macadamia *Macadamia integrifolia**	seeds				
Almond *Prunus amygdalus*	seeds				
Pecan Carya illinoinensis	seeds				
Apple *Malus* spp.	seeds				
Pear *Pyrus* spp.	seeds				
Persimmon *Diospyros* spp. & *Quercus* spp.	seeds, juice of ripe persimmons				
Invertebrates					
All three species may consume insects and insect larvae (including beetle, wasp and moth larvae) from under the bark and within wood of live and dead trees, and (depending on the black-cockatoo species) from the flowers, flower spikes, pith, gall, and cones of various native and introduced species, including *Banksia,* Eucalyptus, and *Xanthorrhoea* spp.					

Table EE: Inventory of food plant species used by black-cockatoos at NBG

Column 1 gives the common name and scientific name for the food plant species, as well as the part of the plant that may be consumed. Insects may also be consumed during feeding events and when present in a plant part. Column 2 indicates whether a behavioural observation (sighting) has been made of black-cockatoos feeding on this plant species within the study area (i.e. in/around NBG): **shaded** = observation made; **unshaded** = no observation. Column 3 indicates whether feeding residues have been observed at the study area and what form of residue was observed *e.g. FC = fruit capsule). Column 4 indicates which black-cockatoo species has been observed feeding of the food plant species at NBG. Column 5 indicates which of the different land uses where feeding on the food plant occurs at NBG (based on behavioural observations or feeding residues).
Codes: Ft = Native Forest; Rn = Rehabilitation Vegetation; FC = fruit capsule; BR = branch; FL = flower; SD = seed; FS = flower spike; SC = seed casing; CO = cone
??? = black-cockatoo species cannot be determined from residue

1 Plant Species	2 Observation	3 Residue	4 Baudin's Cockatoo	4 Carnaby's Cockatoo	4 FRTBC	5 Forest	5 Remnant Vegetation	5 Rehabilitation
TREES								
Jarrah (*E. marginata*) Seed, flower	**Ft**	**FC** **Ft**						
Marri (*Corymbia calophylla*) Seed, flower	**Ft /Rn**	**FC** **Ft / Rn**						
Sheoak (*Allocasuarina fraseriana*) Seed	**Ft**	**FC** **Ft**						
Yarri (*E. patens*) Seed, flower	**Ft**	**FC** **Ft**						
Montery/Radiata Pine (*Pinus radiata*) Seed	**CO**	**CO** **Ft / Rn**				**Sotico Plantation** little feeding on pine wildlings observed		

Table EE (cont.)**: Observations of food plant species used by black-cockatoos at NBG**

Codes: Ft = Native Forest; Rn = Rehabilitation Vegetation; FC = fruit capsule; BR = branch; FL = flower; SD = seed; FS = flower spike; SC = seed casing; CO = cone
??? = black-cockatoo species cannot be determined from residue

1 Plant Species	2 Observation	3 Residue	4 Baudin's Cockatoo	4 Carnaby's Cockatoo	4 FRTBC	5 Forest	5 Remnant Vegetation	5 Rehabilitation
PROTEACEOUS SHRUBS								
Parrot Bush *Banksia sessilis* Seed, flower	**Ft / Rn**	**BR Ft / Rn**						
Pingle *Banksia squarrosa* Seed, flower	**Rn**	**BR Ft / Rn**	**???**	**???**				
Couch Honeypot *Banksia dallaneyi* Unknown – seed?	**FL? SD? Ft**							
Bull Banksia *Banksia grandis* Flower	**Ft / Rn**	**FS Ft**	probable					
Hakea amplexicaulis Prickly Hakea Seed, flower		**BR Rn**	**???**	**???**	**?**			
Hakea cyclocarpa Ram's Horn Seed, flower		**BR Rn**	**???**	**???**	**?**			
Hakea incrassata Marble Hakea Seed, flower		**BR Rn**	**???**	**???**	**?**			
Hakea lissocarpha Honeybush Seed, flower		**BR Rn**	**???**	**???**	**?**			
Hakea prostrata Harsh Hakea BR, SC	**Rn**	**BR SC Ft / Rn**	**???**		**?**			

Hakea undulata Wavy-leaved Hakea Seed, flower	**Rn**	**BR SC Ft / Rn**	**???**		**?**			
Hakea trifurcata Two-leaf Hakea Seed, flower		**BR SC Rn**	**???**	**???**	**?**			
Hakea varia Variable-leaved Hakea Seed, flower		**BR SC Ft / Rn**	**???**	**???**	**?**			

Table FF: Frequency of feeding residues within plots from different land uses: native Jarrah forest, remnant vegetation within a livestock paddock, mine-site rehabilitation, and pine plantation.

The feeding residue category 'Trees' includes three eucalypt species (Jarrah, Marri, Yarri), Forest Sheoak, and Radiata Pine. Sample plots for Native Forest, Remnant Vegetation, and Pine Plantation were 0.625ha (25 m x 25 m) [#]. Sample pots for Mine-Site Rehabilitation were 0.1 ha (10 m x 10 m or 20 m x 5 m) [*].

Mine-site rehabilitation data is from Lee et al. (2010).

	Number of Plots with Feeding Residues Present			
Land Use	*Total*	*Proteaceous Shrubs*	*Trees*	*All Species*
Native Forest[#]	425	29 (6.8%)	132 (31.1%)	159 (37.4%)
Remnant Vegetation[#]	75	0 (0%)	23 (30.7%)	23 (30.7%)
Mine-site Rehabilitation[*]	90	53 (58.9%)	38 (42.2%)	62 (68.9%)
Pine Plantation[#]	25	n/a	25 (100%) Pine: n = 25 Eucalypt: n = 1	25 (100%)

Table GG: Frequency of feeding residues for canopy-forming trees and proteaceous shrubs across landscape positions within native forest and remnant (paddock) vegetation plots

The feeding residue category 'Trees' includes three eucalypt species (Jarrah, Marri, Yarri), Sheoak, and Pine (*Pinus radiata*). The percentages for 'Plots Sampled' are relative to the total number of plots sampled for each land use (n = 425 for Native Forest and n = 75 for Remnant Vegetation. The percentages for 'Trees', 'Proteaceous', and 'Residues Present' are relative to the number of plots for each topographic position (e.g. n = 45 plots sampled for Ridge/Hilltop).
Codes: RI/HT: ridge/hilltop; US: upper slope; MS: mid-slope; LS: lower slope; GU/VF: gully/valley floor; LUN: low undulating terrain (little/no slope)

	RI/HT	US	MS	LS	GU/VF	LUN	Total
Native Forest							
Plots Sampled [% of total]	45 [10.6%]	98 [23.1%]	130 [30.6%]	63 [14.8%]	29 [6.8%]	60 [14.1%]	425
Trees (% of position)	14 (31.1%)	28 (28.6%)	41 (31.5%)	22 (34.9%)	6 (20.7%)	21 (35%)	132
Proteaceous (% of position)	1 (2.2%)	3 (3.1%)	6 (4.6%)	9 (14.3%)	5 (17.2%)	5 (8.3%)	29
Residues Present (% of position)	15 (33.3%)	31 (31.6%)	47 (36.2%)	30 (47.6%)	11 (37.9%)	25 (41.7%)	159
Remnant (Paddock) Vegetation							
Plots Sampled [% of total]	6 [8.0%]	10 [13.3%]	20 [26.7%]	17 [22.7%]	11 [14.7%]	11 [14.7%]	75
Trees	4 (66.7%)	4 (40.0%)	9 (45.0%)	5 (29.4%)	1 (9.1%)	0	23
Proteaceous Shrubs	0	0	0	0	0	0	0
Residues Present	4 (66.7%)	4 (40.0%)	9 (45.0%)	5 (29.4%)	1 (9.1%)	0	23

Table HH: Number of sample plots in which food plants and feeding residues were present by land use (native forest & remnant paddock vegetation) and landscape position

Column 3 gives the number of sample plots in which the food plant was present; percentages are relative to *n* = 425 for native forest and *n* = 75 for remnant vegetation (paddock). Column 4 gives the total number of sample plots in which feeding residues for the food plant were recorded within native forest and remnant vegetation; percentages are *n* = 425 for native forest and *n* = 75 for remnant vegetation (paddock); percentages in […] are relative to the number of plots in which food plants were present (e.g. Jarrah: present in 365 sample plots, feeding residues present in 4 plots – 4/365 = [1.1% of sample plots]. Column 6 gives the number of sample plots with feeding residues for a food plant across landscape positions.
For Marri, the presence of Marri stems within sample plots is also provided.
Codes: RI/HT: ridge/hilltop; US: upper slope; MS: mid-slope; LS: lower slope; GU/VF: gully/valley floor; LUN: low undulating terrain (little/no slope)
Landscape Frequency: (% relative to total number of sample plots for each land use: Native Forest *n* = 425 & Paddock *n* = 75)
Relative Residue Frequency: [% relative to number of sample plots where stems of this species present]
= riparian habitat (valley floor)
Banksia dall. & *Banksia grandis* (dark grid) = cannot determine presence of feeding residues

1 **Plant Species**	**2** **Land Use**	**3** **Stems Present**	**4** **Feeding Residues:** Overall Absent	**5** Present	**6** **Feeding Residues:** Landscape Positions (*n* = number of plots 'Old' residues) [Marri: % of plots where Marri present that contain Marri feeding residues] RI/HT	US	MS	LS	GU/VF	LUN
Jarrah (*Eucalyptus marginata*)	Forest	365 (85.9%)	421 (99.1%)	4 (0.9%) [1.1%]	0	0	2	2 (2)	0	0
	Paddock	38 (50.7%)	65 (86.7%)	10 (13.3%) [26.3%]	1	2	5	2	0	0
Marri (*Corymbia calophylla*)	Forest	264 (62.1%)	299 (70.4%)	126 (29.6%) [47.7%]	28 (8 old)	14 (3 old)	37 (12 old)	21 (7 old)	5 (0 old)	21 (6 old)
	Forest Plots Present				31 [90.3%]	60 [23.3%]	80 [46.3%]	30 [70.0%]	11 [45.5%]	52 [40.4%]
	Paddock	10 (13.3%)	65 (86.7%)	10 (13.3%) [100%]	3 (2 old)	2 (1 old)	3	2	0	0
Sheoak (*Allocasuarina fraseriana*)	Forest	166 (39.1%)	420 (98.8%)	5 (1.2%) [3.0%]	1	2	2	0	0	0
	Paddock	0	75 (100%)	0	0	0	0	0	0	0
Yarri (*E. patens*)	Forest	6 (1.4%)	424 (99.8%)	1 (0.2%) [16.7%]	0	0	0	0	1 (1 old)	0
	Paddock	15 (20.0%)	70 (93.3%)	5 (6.7%) [33.3%]	0	0	1	3	1#	
Parrot Bush *Banksia sessilis*	Forest	112 (26.4%)	413 (97.2%)	12 (2.8%) [10.7%]	1	3	2	2	0	4

	Paddock	0	75 (100%)	0	0	0	0	0	0	0
Pingle *Banksia squarrosa*	Forest	5 (1.2%)	424 (99.8%)	1 (0.2%) [20.0%]	0	0	0	0	1	0
	Paddock	0	75 (100%)	0	0	0	0	0	0	0
Hakea prostrata	Forest	45 (10.6%)	380 (89.4%)	14 (3.3%) [31.1%]	0	0	2	5	5	2
	Paddock	0	75 (100%)	0	0	0	0	0	0	0
Hakea undulata	Forest	23 (5.4%)	402 (94.6%)	3 (0.8%) [13.0%]	0	0	0	1	2	0
	Paddock	0	75 (100%)	0	0	0	0	0	0	0
Hakea varia	Forest	NR	NR	3	0	0	0	1	2	0
	Paddock	NR	NR	0	0	0	0	0	0	0

Table II: Frequency of feeding residues within plots from primary habitat types within native forest plots

The feeding residue category 'Trees' includes three eucalypt species (Jarrah, Marri, Yarri), Sheoak, and Pine (*Pinus radiata*). The percentages in column 1 are relative to the total number of Native Forest plots (n = 425 plots). The percentages in column 2 are relative to the number of plots of each habitat type (e.g. n = 94 plots for 'Jarrah'). The percentages (in parentheses) in column 3-5 are relative to the number of plots of each habitat type; 'Proteaceous' is the percentage relative to the number of plots containing Proteaceous feeding residues (n = 29), 'Trees' is the percentage relative to the number of plots containing feeding residues from canopy-forming trees (n = 132), 'Total' is the percentage relative to the total number of plots containing feeding residues (of any kind) (n = 159).

Primary Habitat Type	1 **Total** (% of plots) n = 425	2 **No Residues Present** (% of habitat-type plots)	**Plots with Feeding Residues Present** 3 *Proteaceous Shrubs* (% of plots for this habitat-type) [% of plots with proteaceous residues]	4 *Trees* (% of plots for this habitat-type) [% of plots with 'trees' residues]	5 *All Species* (% of plots for this habitat-type) [% of total plots]
1. Jarrah	94 (22.1%)	66 (70.2%)	5 (5.3%) [17.2%]	23 (24.5%) [17.4%]	28 (29.8%) [17.6%]
2. Jarrah-Marri	70 (16.5%)	33 (47.1%)	2 (2.9%) [6.9%]	36 (51.4%) [27.2%]	37 (52.9%) [23.3%]
3. Jarrah-Sheoak	69 (16.2%)	40 (58.0%)	0	29 (42.0%) [22.0%]	29 (42.0%) [18.2%]
4. Jarrah-Wandoo	16 (3.8%)	14 (87.5%)	2 (12.5%) [6.9%]	1 (6.3%) [0.8%]	2 (12.5%) [1.3%]
5. Jarrah Mixed	26 (6.1%)	11 (42.3%)	1 (3.8%) [3.5%]	14 (53.9%) [10.6%]	15 (57.7%) [9.4%]
6. Marri Dominant	32 (7.5%)	11 (34.4%)	1 (3.1%) [3.5%]	20 (62.5%) [15.2%]	21 (65.6%) [13.2%]
7. Sheoak/ Sheoak Dominant	19 (4.5%)	17 (89.5%)	0	2 (10.5%) [1.5%]	2 (10.5%) [1.5%]
8. Wandoo Dominant	25 (5.6%)	20 (80.0%)	3 (12.0%) [10.3%]	2 (8.0%) [1.5%]	5 (20.0%) [3.1%]
9. Wandoo	60 (14.1%)	47 (78.3%)	11 (18.3%) [37.9%]	2 (3.3%) [1.5%]	13 (21.6%) [8.2%]
10. Other	14 (3.3%)	7 (50.0%)	4 (28.6%) [13.8%]	3 (21.4%) [2.3%]	7 (50.0%) [4.4%]
Total	425	266	29	132	159

Table JJ: Frequency of feeding residues within plots from secondary habitat types within native forest plots

The feeding residue category 'Trees' includes three eucalypt species (Jarrah, Marri, Yarri), Sheoak, and Pine (*Pinus radiata*). The percentages in column 1 are relative to the total number of Native Forest plots (n = 425 plots). The percentages in column 2 are relative to the number of plots of each habitat type (e.g. n = 94 plots for 'Jarrah'). The percentages (in parentheses) in column 3-5 are relative to the number of plots of each habitat type; 'Proteaceous' is the percentage relative to the number of plots containing Proteaceous feeding residues (n = 29), 'Trees' is the percentage relative to the number of plots containing feeding residues from canopy-forming trees (n = 132), 'Total' is the percentage relative to the total number of plots containing feeding residues (of any kind) (n = 159).

Secondary Habitat Type	**1** **Total** (% of plots) n = 425	**2** **No Residues Present** (% of habitat-type plots)	**Plots with Feeding Residues Present**		
			3 *Proteaceous Shrubs* (% of plots for this habitat-type) [% of plots with proteaceous residues]	**4** *Trees* (% of plots for this habitat-type) [% of plots with 'trees' residues]	**5** *All Species* (% of plots for this habitat-type) [% of total plots]
1. Dryandra Thicket	57 (13.4%)	33 (57.9%)	12 (21.1%) [41.4%]	14 (24.6%) [10.6%]	24 (42.1%) [15.1%]
2. Wattle Thicket (*Acacia celastrifolia*)	19 (4.5%)	11 (57.9%)	0	8 (42.1%) [6.1%]	8 (42.1%) [5.0%]
3. Other e.g. *Melaleuca* spp., *E. rudis*, swamp, granite outcrop	6 (1.2%)	4 (66.7%)	1 (16.7%) [3.5%]	2 (33.3%) [1.5%]	2 (333%) [1.3%]

Table KK: Number of trees bearing potential hollows and number of plots with feeding residues across grid units, land tenure, and land use

Sample Site: 1 km x 1 km grid (*n* = 25 plots); Tenure: land tenure arrangements; Use: Land use
Jar: Jarrah Mar: Marri Wan: Wandoo Tree: eucalypt, sheoak, or pine Proteaceous: *Banksia* or *Hakea*
NBG: NBG tenements; ACQ: eastern acquired lands; STA: State Forest; HOT: Alcoa Hotham Farms; SOT: Sotico
NF: native forest; PD: paddock; PI: pine

			No. of trees with potential hollows				**No. of plots with feeding residues**		
Site	**Tenure**	**Use**	*Jar*	*Mar*	*Wan*	TOTAL	*Tree*	*Proteaceous*	Total
1	NBG	NF	4	3	0	7	9	1	9
2	ACQ	NF	3	0	0	3	10	0	10
3	NBG	NF	2	2	1	5	16	2	18
4	ACQ	NF	3	0	0	3	8	0	8
5	ACQ	NF	2	1	2	5	2	4	6
6	ACQ	NF	0	0	2	2	0	13	13
7	ACQ	NF	1	0	0	1	2	4	6
8	ACQ	NF	0	0	1	0	6	0	6
9	ACQ	NF	2	0	0	0	6	0	6
10	ACQ	NF	0	0	0	0	8	0	8
11	ACQ	NF	3	0	0	0	1	1	2
12	NBG	NF	3	3	0	6	12	1	13
13	NBG	NF	0	1	0	1	16	0	16
14	ACQ	NF	3	1	0	0	6	1	7
15	ACQ	NF	1	1	0	3	13	1	13
16	ACQ	NF	0	1	0	1	7	1	8
17	STA	NF	5	0	0	5	10	0	10
18	HOT	PD	2	0	1	3	7	0	7
19	HOT	PD	0	1	0	3	7	0	7
20	HOT	PD	0	0	0	0	9	0	9
21	SOT	PI	0	0	0	0	25	0	25

C. Potential Nest Hollows

4.7 Abundance and distribution of potential hollow-bearing trees

Ground-based observations identified 59 potential hollow-bearing trees within 57 sampling plots within Native Forest and Paddock (remnant vegetation) sample plots (13.4% of plots) (Table LL). These include: 53 potential hollow-bearing trees within 51 plots in Native Forest sample plots (12.0% of native forest plots) and 6 potential hollow-bearing trees within 6 Paddock sample plots [8.0% of remnant (paddock) vegetation]. Nine trees (15.3%) had multiple potential hollows.

4.8 Characteristics of potential hollow-bearing trees

Bees were present in only 1 of 59 (1.7%) potential hollows, suggesting a low prevalence of beehives within potential tree hollows in the study area. The mean DBH of potential hollow-bearing trees was $\geq$ 90 cm for all the species (Table MM). Other characteristics of potential hollow-bearing trees are described in Table MM.

4.9 Estimates of potential hollow abundance

Finn et al. (2011) estimated the proportions of potential black-cockatoo hollows observed in Jarrah, Marri, and Wandoo trees during ground-based surveys that post-felling inspection indicated were actually 'large' hollows (Appendix 2). They found that only 31.5% of potential black-cockatoo hollows observed in Jarrah were actually 'large' hollows and therefore potentially suitable for nesting (not considering other factors influencing hollow suitability, e.g. specific interior dimensions, aspect and height of hollow, occupancy by other species). In contrast, more than half of the potential black-cockatoo hollows observed in Marri (55.6%) and Wandoo (66.7%) were 'large' hollows. These are estimates of 'large' hollows; these hollows may not be suitable cavities for nesting for several reasons. The actual density of potential is likely to be smaller than these estimates. Application of these proportions to the results from this study provides these estimates of hollow prevalence (assuming 1 hollow per tree)[10]:

Black-cockatoos were observed occupying two hollows within sampling plots, indicating nesting activity. This gives a potential density of probable nests of 7.53 nests per km^2 (0.0753 nests per ha), but this is based on a very small sample size.

Biggs (2008) used belt transects to estimate the abundance of potential black-cockatoo hollows at five sites within NBG tenements and in one site in the land exchange area to the north of site. Methods for identifying hollows were similar to those used for this study. Biggs (2008) used four transects per site (of varying length), with one transect positioned with four landscape positions: Ridge-top, Upper Slope, Lower Slope, and Woodland (valley floor) (Appendix 2). If the hollow frequencies observed during transect sampling in Biggs (2008) are used to estimates of 'large' hollow abundances [using the Finn et al. (2011) proportions] the estimates are similar to that for the this study, with the exception of Marri (Appendix 3).

10 1 km^2 = 100 ha

Table LL: Distribution of trees bearing potential black-cockatoo hollows by tree species across landscape, land tenure, and land use

*Tree species not determined: *n* = 1 tree

	Jarrah	*Marri*	*Wandoo*	*Yarri*	*Total*
Native Forest					
TOTAL	34	14	8	2	58* (*n* = 56 plots, 13.6%)
Gully/Valley Floor (*n* = 29 plots)	0	1	1	0	2 (*n* = 2 plots, 6.9%)
Lower Slope (*n* = 63 plots)	6	7 (*n* = 6 plots)	3	0	16 (*n* = 15 plots, 23.8%)
Mid-Slope (*n* = 130 plots)	12	3 (*n* = 2 plots)	2	0	17 (*n* = 16 plots, 12.3%)
Upper Slope (*n* = 98 plots)	5	2	1	0	8 (*n* = 8 plots, 8.2%)
Ridge/Hilltop (*n* = 45 plots)	4	0	1	0	5 (*n* = 5 plots, 11.1%)
Low Undulating (*n* = 60 plots)	5	1	1	0	7 (*n* = 7 plots, 11.7%)
Other					
Acquired Lands (*n* = 300 plots)	17	4	4	0	25 (*n* = 25 plots, 5.9%)
Other NBG Lands (*n* = 100 plots)	9	9 (*n* = 7 plots)	1	0	19 (*n* = 17 plots, 17.0%)
Paddock (*n* = 75 plots)	2	1	1	2	6 (*n* = 6 plots, 8.0%)
State Forest (*n* = 25 plots)	5	0	0	0	5 (*n* = 5 plots, 20.0%)

Table MM: Characteristics of trees in Native Forest identified as having potential hollows

Jarrah: *n* = 34; Marri: *n* = 14; Wandoo: *n* = 8; Yarri: *n* = 2; species not determined: *n* = 1
* not including trees with hollow butts
# Some trees had more than one hollow or hollow was not clearly one location.

	Jarrah	Marri	Wandoo	Yarri	Total
% Hollow: Trunk#	50.0% (17/34)	14.3% (2/14)	12.5% (1/8)	0	32.8% (19/58)
% Hollow: Branch#	67.6% (23/34)	57.1% (8/14)	87.5% (7/8)	100% (2/2)	51.7% 30/58
% Hollow: Tube#	9.1% (3/33)	35.7% (5/14)	37.5% (3/8)	0	19.0% (11/58)
DBH -- mean (cm)	92.5 ± 6.1* (*n* = 24)	90.8 ± 6.5 (*n* = 14)	95.6 ± 7.6 (*n* = 7)		93.1 ± 3.9* (*n* = 47)
DBH -- range (cm)	51- 178*	59 -145	63 -114		51- 178*
% Stags	32.4% (11/34)	50% (7/14)	25% (2/8)	50% (1/2)	37.9% (22/58)
% Hollow opening ≥20 cm (apparent)	88.2% (30/34)	78.6% (11/14)	87.5% (7/8)	100% (2/2)	86.2% (50/58)
% hollow butt	26.5% (9/34)	NA	NA	50% (1/2)	
% fire scar present	87.1% (27/31)	72.7% (8/11)	75% (6/8)	100% (2/2)	80.8% (42/52)
Crown Senescence (mean)	5.7 (*n* = 33) range: 2 -10	5.3 (*n* = 14) range: 1 - 9	4.8 (*n* = 8) range: 1.5 - 9	3 (*n* = 2) range: 2 - 4	5.4 (*n* = 58) range: 1 - 10
Dead Branch Order (mean)	6.0 (*n* = 33) range: 1.5 - 9	6.4 (*n* = 14) range: 3 - 8	5.9 (*n* = 8) range: 1.5 - 8	6.5 (*n* = 2) range: 6 - 7	6.1 (*n* = 58) range: 1.5 - 9
Crown Lost (mean)	2.0 (*n* = 32) range: 1 - 5	2.4 (*n* = 14) range: 1 - 5	1.8 (*n* = 8) range: 1 - 4	1 (*n* = 2) range: 1 - 1	2.1 (*n* = 57) range: 1 - 5
% crown dead (mean)	59.4% (*n* = 32) range: 9 - 100	59.4% (*n* = 13) range: 6 - 100	41.1% (*n* = 8) range: 6 - 100	53 (*n* = 2) range: 6 - 100	57.3% (*n* = 57) range: 6 - 100

Table NN: Estimates of potential black-cockatoo hollows based on 'large' hollow proportions

area of sampling plot: 25 x 25 m = 625 m^2
area of all plots sampled (Native Forest) = 425 x 625 m^2 = 0.266 km^2 = 26.6 ha

Jarrah:

n = 34 trees bearing potential black-cockatoo hollows observed during ground-based observations within sampling plots (Native Forest: *n* = 32; Paddock: *n* = 2)
Native Forest: 32 hollows observed x 0.315 large hollow proportion = **10.1 'large' hollows**
10.1 trees / 0.266 km^2 = 37.9 trees per km^2 = **0.379 trees with 'large' hollows per ha**

Marri:

n = 14 trees bearing potential black-cockatoo hollows observed during ground-based observations within sampling plots (Native Forest: *n* = 13; Paddock: *n* = 1)
Native Forest: 13 hollows observed x 0.556 large hollow proportion = **7.2 'large' hollows**
7.2 trees / 0.266 km^2 = 27.2 trees per km^2 = **0.272 trees with 'large' hollows per ha**

Wandoo:

n = 8 trees bearing potential black-cockatoo hollows observed during ground-based observations within sampling plots (Native Forest: *n* = 7; Paddock: *n* = 1)
Native Forest: 7 hollows observed x 0.667 large hollow proportion = **4.7 'large' hollows**
4.7 trees / 0.266 km^2 = 17.6 trees per km^2 = **0.176 trees with 'large' hollows per ha**

Yarri:

n = 2 trees bearing potential black-cockatoo hollows observed during ground-based observations within sampling plots (Native Forest: *n* = 0; Paddock: *n* = 2)
Native Forest: N/A

5. DISCUSSION

5.1 Black-Cockatoo Sightings

OBJECTIVE ONE: Describe general patterns of species occurrence, distribution, and breeding activity within the eastern acquired lands, based on sightings of black-cockatoos and observations of feeding residues.

Summary

All three black-cockatoo species were observed within the acquired lands and observations of feeding residues also suggest that all three species use the acquired lands as a feeding habitat. Nesting activity for two species, Carnaby's Cockatoos and FRTBC, was also observed.

Baudin's Cockatoos

The peak abundance period for Baudin's Cockatoos at NBG is between March/April to September/October, so the low number of Baudin's Cockatoos observed in not reflective of their use of the area; this is also supported by the frequency of Marri feeding residues bearing marks indicative of feeding by Baudin's Cockatoos. Although the Boddington area lies to the north of the main breeding area for Baudin's Cockatoos (southern Jarrah-Marri forest and the Karri forest), the presence of small numbers of birds during the summer period (breeding season) suggests that a small number of Baudin's Cockatoos may breed in the area. This would also reflect evidence that the breeding distribution of Baudin's Cockatoos is changing (R. Johnstone, WA Museum, personal communication). Generally, during the non-breeding Baudin's Cockatoos occur at NBG in small to medium-sized flocks (5-50+ birds) that remain in the area for a few days feeding on available Marri fruits, before moving on. This movement and residency pattern contrasts with FRTBC who tend to be resident within an area, and spend days-weeks at sites exploiting the food sources available there.

Carnaby's Cockatoos

Carnaby's Cockatoos appear to use the NBG (and Sotico) area in several ways: (a) as a short-term feeding habitat (e.g. for flocks transiting between feeding areas on the Swan Coastal Plain and breeding sites in the Wheatbelt); (b) as a longer-term feeding habitat (i.e. weeks to months); and (c) as a breeding habitat. This is reflected in the variation in group sizes observed, e.g. very large flocks present for short periods, generally using abundant food sources in rehabilitation areas and in the Sotico pine plantations vs. small groups of ~5-20 birds vs. pairs and singletons (male or female of a pair).

Most of the feeding on proteaceous shrubs at NBG can probably be attributed to Carnaby's Cockatoos, although Baudin's Cockatoos may also feed on *Banksia* and *Hakea* species, and—more rarely—FRTBC as well. In this context, it is worthwhile to note that 19 of the 29 (65.5%) plots containing proteaceous feeding residues occurred in sample plots within 1 km of the eastern margin of the acquired lands (sample sites 6, 7, 11, and 16) and 23 of the 29 (79.3%) occurred in sample plots <2.5 km from the eastern margin of the acquired lands (sample sites 5 and 15). Three sample sites in the southeastern corner of the acquired lands (sample sites 5, 6, and 7) contained 21 (72.4%) of these sample plots, indicating a concentration of feeding activity for Carnaby's Cockatoos in this area.

This finding, when coupled with intensive feeding in the pine plantation (only Carnaby's have been observed feeding on pine at Sotico) and frequent proteaceous feeding residues within rehabilitation areas at NBG suggests that the feeding distribution of Carnaby's Cockatoo focuses on: (a) the Sotico pine plantation, (b) rehabilitation

areas, and (c) Jarrah/Wandoo woodland areas towards the margins of the acquired lands. There are exceptions to this, which include feeding on *Banksia sessilis, Banksia dallanneyi,* Marri (with soft green fruits), and Jarrah. Of the three species, Carnaby's Cockatoos appear the most catholic and thus potentially the species most responsive to changes in food availability. Food selection may also reflect individual and flock/population-level preferences. Breeding pairs will require an adequate food source to sustain them for at least two months sometime between ~August and December.

FRTBC

Of the three species, FRTBC are the most likely to be reliant on food availability in the general NBG area across the course of an entire year, as their ecology generally a relatively small and defined home range, in contrast to the more migratory white-tailed species. Their metabolic ecology also differs and, as their basal metabolic rate is higher than the other two species, they must both eat more and experience higher energetic costs of locomotion (Cooper et al. 2003).

Importance of permanent water sources

The availability of water is likely to be a critical determinant for the distribution of black-cockatoos during the warm/low rainfall months, and on location of nest sites. Black-cockatoos must drink daily and, as such, are not likely to travel more than a few kilometres away from a known water source during warmer months. This may account for the predominance of sightings along the eastern margin of the acquired lands (adjacent to farm dams in the paddocks to the east) and around the NBG site and Hotham Farms paddocks (sumps and farm dams occur throughout these areas). Nest sites located to date are within 2 km of a permanent water source, which would require at most 20-30 minutes to travel between the nest site and the water source, based on a probable flight speed of 7-8 km/h.

5.2 Food Plants

OBJECTIVE TWO: Establish a list of food plant species for black-cockatoos, based on behavioural observations and feeding residues, and describe the general availability of these food sources within the acquired lands.
OBJECTIVE THREE: Compare black-cockatoo feeding activity across four different land uses: (a) native forest, (b) mine-site rehabilitation, (c) remnant vegetation within a livestock paddock, and (d) pine plantation, based on frequencies of feeding residues within vegetation sampling plots.

Black-cockatoo food sources

Table PP suggests the breadth of food sources that the three black-cockatoo species will consume. However, the potential breadth of diet is misleading as generally a small number of plant species will comprise the vast majority of the diet. For example, 90% of the diet of FRTBC is thought to consist of Jarrah and Marri. Similarly, during certain periods Carnaby's Cockatoos will consume a diet that consists almost entirely of seeds from Radiata Pine (Finn et al. 2009; D. Saunders, unpublished data). Likewise, Marri is generally considered the main food source for Baudin's Cockatoos. Thus, while black-cockatoos may consume a range of food plants, most of the diet will consist of a small number of food sources, with other species providing a supplementary food source (or a main food source but for a limited period of time). Carnaby's Cockatoos are the most catholic of the three, and will typically shift from one food plant to another as food plants shift in availability and/or quality. An additional consideration is the effect of phenology, and how seasonal and inter-annual variation in flowering and fruiting

cycles will affect the availability of a particular resource, e.g. what may be an abundant resource at one time of year (e.g. when flowering) or within one year (a 'peak' year in flowering and fruiting), maybe not be in the following months or years. For these reasons, assessments of food availability need to consider temporal variation and should generally focus on the principal food sources likely to be available.

The low prevalence of feeding residues for Jarrah contrasts with Biggs (2008), who found a similar prevalence of Jarrah and Marri feed trees at NBG. This difference probably reflect inter-annual variation in the flowering (and subsequent fruiting) of Jarrah and Marri, with seasonal variation in fruit quality, differences in the persistence of Jarrah and Marri residues, and local-scale changes in the distribution of FRTBC also potential contributing factors. The findings do, however, indicate that feeding on Marri was far more intensive than for Jarrah for at least one year prior to the study and across the study area landscape. It is also worth noting that FRTBC (most likely) were feeding on Jarrah within the Hotham Farms remnant vegetation, as Jarrah feeding residues were observed in 26.3% of the plots in which Jarrah stems were present. This suggests that: (a) the availability and quality of Jarrah fruits in the Hotham Farms remnant vegetation differs from that in the native forest within the acquired lands (e.g. because of different flowering cycles) and/or (b) that the absence of Jarrah feeding residues from native forest plots reflects a low level of activity/presence of FRTBC within these areas. The latter hypothesis is consistent with the higher frequency of Baudin-type Marri residues, and suggests that FRTBC may shift around different parts of the home range depending on food availability.

5.3 Potential Nest Hollows

OBJECTIVE FOUR: Examine the abundance of potentially suitable nest hollows with the acquired land, based on counts of potential hollow-bearing trees from ground-based surveys and extrapolation of these counts to a landscape-scale.

Estimated abundance of potentially suitable hollows

Ground-based observations identified 59 potential hollow-bearing trees within 57 sampling plots within native forest and remnant (paddock) vegetation (13.4% of plots), including 53 potential hollow-bearing trees within 51 plots in native forest (12.0% of native forest plots). These are similar to the hollow prevalences observed in Biggs (2008). Finn et al. (2011) estimated the proportions of potential black-cockatoo hollows observed in Jarrah, Marri, and Wandoo during ground-based surveys that were actually 'large' hollows (based on post-felling inspection of observed hollows). They found that only 31.5% of potential black-cockatoo hollows observed in Jarrah were actually 'large' hollows and therefore potentially suitable for nesting (not considering other factors influencing hollow suitability, e.g. specific interior dimensions, aspect and height of hollow, occupancy by other species). In contrast, more than half of the potential black-cockatoo hollows observed in Marri (55.6%) and Wandoo (66.7%) were 'large' hollows.

These are estimates of 'large' hollows; which may not be suitable cavities for nesting for several reasons, thus he actual density of potential is likely to be smaller than these estimates. Application of these proportions to the results from this study provides these estimates of hollow prevalence (assuming 1 hollow per tree) of 37.9 Jarrah 'hollow' per km^2, 27.2 Marri 'hollows' per km^2, and 17.6 Wandoo 'hollows' per km^2.

These densities should be viewed with great care, given the caveats above and the additional caveats that: (a) black-cockatoos appear to only rarely nest within Jarrah within the Jarrah-Marri forest (R. Johnstone, WA Museum, personal communication) and (b) nest-site suitability is almost certainly linked to food availability and

nearby (<2 km distant) presences of a permanent water source. These factors likely mean that nesting activity is largely restricted to suitable Marri and Wandoo hollows located near to sumps, swamps, and farm dams (where breeding occurs during low rainfall periods).

Previous estimates of hollow abundance within the Jarrah Forest

Compared to south-eastern Australia, few studies have examined the occurrence of large hollows in the Jarrah Forest (Inions et al. 1989, McComb et al. 1994, Whitford and Williams 2001, Whitford 2002, Whitford and Williams 2002). McComb et al. (1994) reported that, of a sample of 292 hollows from Jarrah (n = 282 trees) and Marri (n = 81 trees) in 9 Jarrah forest logging coupes, only 1 was of suitable size for FRTBC. This study considered only trees harvested during logging operations, and thus excluded trees left standing in logging coupes, including dead trees (stags), senescent trees which were not suitable for timber, and conserved habitat trees. Whitford (2002) and Whitford and Williams (2002) published density estimates for hollows of different sizes in the jarrah forest, based on hollow frequencies in trees of different diameter-at-breast-height (DBH) in a destructive sample of 211 Jarrah and Marri trees, and estimates of stand structure across the State Forest available from State Forest inventories. Although the studies did not include density estimates for hollows potentially suitable for FRTBC, they reported found hollows of sufficient size for FRTBC within plots sampling a total of 14.4 ha, indicating a density of one potentially suitable hollow per 1.1 ha

Abbott (1998) extended these studies by estimating hollow availability for FRTBC using: (a) State Forest inventory estimations for the abundance of trees of different DBH, and (b) an estimation of frequency of large hollows relative to DBH within the (then-unpublished) dataset for felled Jarrah and Marri trees from Whitford (2002) and (Whitford and Williams 2002). Based on these data, Abbott (1998) estimated that the availability of hollows approximated 0.89 suitable hollows per ha (1 hollow per 1.1 ha), giving, in State Forest areas, FRTBC 104-167 available hollows within an average reported home range of 116-187 ha.

5.4 Statement of Habitat Values

This study demonstrates that the eastern acquired lands provide feeding habitat for all three black-cockatoo species and breeding habitat for Carnaby's Cockatoos and FRTBC. While the relative value of these habitats is difficult to measure, the overall value of the area is enhanced by proximity of food sources in the Sotico pine plantation and in mine-site rehabilitation areas and water sources within NBG tenements and the farmlands to the east. As FRTBC may breed throughout the year and breeding effort is known to vary greatly from year to year, it is difficult to determine how many pairs are likely to breed within the acquired lands. However, the local FRTBC population associated with the eastern acquired lands and adjacent is unlikely to exceed 150-250 birds, based on sightings and group sizes. Carnaby's Cockatoos have a more defined breeding season, and while abundance is also difficult to measure, observed nesting rates and observations of breeding/nesting behaviour (e.g. single birds flying to/from a water site) suggest that eastern acquired lands could contain between 20 – 50 breeding pairs, with the number breeding each year varying. Though the eastern acquired lands have experienced a different forest management regime (e.g. logging intensity, prescribed burning regime, retention of felled and fallen logs) than adjacent State Forest habitats, and so differences may occur in the availability of food and potential nest hollows.

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7. LIST OF PERSONNEL

Hugh Finn	Sightings and Plot Sampling
Jessica Lee	Plot Sampling in Mine-site Rehabilitation

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9. APPENDIX

Appendix 1: Black-cockatoo sightings at NBG during plot sampling

Date	Area (site)	Plot or GPS Position	Location Description	Time	Species	NOTE
October 2009						
14-Oct-09	NBG		Rehabilitation are south of Main Gate Security	1805	Carn (FRTBC)	3 feeding on rehab vegetation; FRTBC also heard
16-Oct-09	NBG	0442405 6377119	Along L Pit haul road	0543	Carn	3 feeding on *Banksia grandis* flower spikes
16-Oct-09	ACQ	0445306 6377053	House Brook Road	0625	FRTBC (Carn)	3 flying to east after brief roost; Carnaby's Cockatoo calls heard
16-Oct-09	ACQ	0447493 6374755	Off Roberts Road	0724	Carn	Pair (2) copulating
16-Oct-09	ACQ	0447537 6374873	Roberts Road (just before junction with Boggy Brook)	0715	FTRBC	Pair (2): female within hollow, male on branch; also FRTBC heard to NW
16-Oct-09	ACQ	0449205 6378004	Boundary Road (north of Roberts Road)	0822	FTRBC	Pair (2): roosting, feeding on Marri
16-Oct09	ACQ	0449415 6379606	Boundary Road	0843	FRTBC	4 feeding on Marri; near paddock
16-Oct-09	ACQ	0449274 7379843	Just west of Boundary Road	0900	FRTBC (Carn)	At least 10 short-roosting in Wandoo; Carnaby's Cockatoo calls heard
16-Oct-09	ACQ		Near junction of Twinbridge Road & Boundary Road	0930	Carn	5 flying to SSE (from Sotico?)
27-Oct-09	ACQ	0449208 6372891	To SW of sewage treatment plant (north of site access road)		FRTBC	Pair (2): female in hollow, male on branch
27-Oct-09	HOT	0441943 6372340	NE corner of Hotham Farms (south of D4 access)	1040	FRTBC (Carn)	18-27 (best = 21) feeding on Marri (and Jarrah); Carnaby's Cockatoo calls heard
27-Oct-09	NBG	0441188 6377486	Edge of Q pit rehabilitation	1350	FRTBC (Carn)	4 roost-resting in Marri & Jarrah; Carnaby's Cockatoo calls heard to east
30-Oct-09	HOT	0443252 6373242	Hill east of Siding Road	0800	Baud	Pair (2) short-roost
30-Oct-09	HOT	0442477 6373858	East of Siding Road	1045	Carn	4 roost-rest in Marri & Jarrah

30-Oct-09	HOT	0442434 6373868	East of Siding Road	1115	FRTBC	Pair (2) sociliase
November 2009						
10-Nov-09	NBG		Boomerang Swamp		FRTBC	Female in hollow
10-Nov-09	NBG	04442991 6377565	Tadpole Road		Carn	Female in hollow
10-Nov-09	NBG	0441958 6373747	West of Siding Road		FRTBC	2 feeding on Jarrah
11-Nov-09	NBG	0443060 6374425	Roberts Road		Carn (FRTBC)	Female Carnaby's Cockatoo in hollow; FRTBC also in area
11-Nov-09	ACQ	0445479 6375693	Near junction of Roberts & Housebrook		Carn	Female in hollow
11-Nov-09	ACQ		South of Roberts Road		Carn	Female in hollow
11-Nov-09	NBG		Near Main Gate for mine		Carn	7 short-roost
11-Nov-09	SOT	0444577 6383574	Western edge of Sotico	1620	Carn	>20 feeding on *Banksia sessilis*
12-Nov-09	NBG	0439331 6384943	NW of F1 RDA	0930	Carn	20-25 feeding on Marri and *Banksia grandis*
12-Nov-09	NBG	0440997 6378722	Near Q pits	1050	Carn	25-35 feeding on rehab vegetation; feeding on *Hakea undulata*
12-Nov-09	NBG	0440922 6379919	Narrow Pipeline Road	1320	Carn	20-30 feeding on *Banksia grandis* and *Banksia sessilis*
25-Nov-09	NBG	0442334 6377144	Just south of L pit haul road	0548	Carn	3 feed on *Banksia grandis* and also ground forage (food plant not known)
25-Nov-09	ACQ		West of Boundary Road, just south of Chalk Road	0630	Carn	Heard to west, saw 1
25-Nov-09	ACQ	0449285 6380370	Just west of Boundary Road	0640	FRTBC	3 short-roost in Wandoo
January 2010						
12-Jan-10	ACQ 5	101	To north of Roberts Road		Carn	CBC calling to north of Roberts Road; $n = 2$ passed with ≥ 10 spread over a large area
12-Jan-10	ACQ 5	0447109 6374898	South of Roberts Road		Carn	2 short-roost, larger assemblage to north of Roberts Road

14-Jan-10	ACQ 9	205			Carn	Heard Carnaby's Cockatoo's to the south
15-Jan-10	ACQ 10	250			FRTBC	Heard FRTBC to northeast
15-Jan-10	ACQ 10	245			FRTBC	FRTBC heard to the east
19-Jan-10	ACQ 6	136	Rehab area at old site village area	1830	FRTBC	To south; juvenile plea heard
19-Jan-10	ACQ 6	137	North of new site village	1700	FRTBC	To southeast; flying north
19-Jan-10	ACQ 6	0448786 6373297	North of new site village	1950	Carn	Large dam for drinking; sample plot 142; 6 Carnaby's in area; one drink from dam
20-Jan-10	ACQ	0445987 6375527	Roberts Road (west of Boggy Brook)	1315	FRTBC	2 feeding on Sheoak
21-Jan-10	ACQ 11	255		0700	FRTBC	FRTBC to east-southeast
21-Jan-10	ACQ 11	264		1215	Baud	BBC to east; alarm call with two wedge-tail eagles soaring above
22-Jan-10	ACQ		East of junction of Twinbridges Road & Boundary Road	0650	FRTBC	>2 around paddock
22-Jan-10	ACQ		East of Boundary Road	0720	FRTBC	Group in paddock to east
22-Jan-10	ACQ		Boundary Road	0729	FRTBC	FRTBC in area just north of gate at south end of Boundary Road
February 2010						
12-Feb-10	ACQ 16	379			FRTBC & Carn	FRTBC to south and CBC to southeast
12-Feb-10	ACQ 16	380			FRTBC	FRTBC calling to south
12-Feb-10	ACQ 16	0448994 6380089		0936	FRTBC (Carn)	5 short-roost and feed on Marri; Heard Carnaby's Cockatoo's to the north
17-Feb-10	NBG 13	303			FRTBC	4 FRTBC flew to east-southeast
17-Feb-10	NBG 13	316	Pillow Swamp		FRTBC	FRTBC to west-southwest side of Pillow Swamp
17-Feb-10	NBG 13	316	Pillow Swamp	0650	Baud	Near plot 316; 6 roost-short

17-Feb-10	NBG 13	321	Pillow Swamp		FRTBC	FRTBC calling to north
17-Feb-10	NBG 13	321	Pillow Swamp	0615	Baud	BBC near Pillow Swamp
17-Feb-10	NBG		Accommodation village	1915	FRTBC	Roosting at NE edge of village
18-Feb-10	ACQ		North of L pits	0550	Carn	Carnaby's Cockatoos calling
18-Feb-10	ACQ		Boundary Road just south of Chalk Brook Road	0618	FRTBC	Heard FRTBC
18-Feb-10	ACQ	0449358 6379952	Boundary Road	0628	FRTBC	FRTBC in paddock to east
18-Feb-10	ACQ	0449344 6375589	Boundary Road	0650	FRTBC	3 short-roost
18-Feb-10	ACQ	0449420 6375505	East of Boundary Road	0700	FRTBC	11 feeding on Marri
18-Feb-10	ACQ	0449225 6373440	East of Boundary Road	0730	Carn (FRTBC)	≥8 Carnaby's Cockatoos; probably feeding on *Banksia sessilis*; also heard FRTBC
18-Feb-10	ACQ	0449263 6373670	Boundary Road	0823	FRTBC	2 short-roost; other FRTBC to NW
18-Feb-10	ACQ		Boundary Road	0830	FRTBC	FRTBC in whole area within paddocks from Roberts Road towards Old Soldiers Road, some also to west of Boundary Road
March 2010						
15-Mar-10	HOT 19	464	Hotham Farms	0630	FRTBC	FRTBC to south at edge of creekline
15-Mar-10	HOT 19	457	Hotham Farms	1720	FRTBC	FRTBC on ridge to the north
15-Mar-10	HOT 19	462	Hotham Farms	1725	FRTBC	FRTBC to west-southwest; at dam? = >1km away
18-Mar-10	SOT 21	NA	Sotico Pine	0700	Carn	CBC to west
19-Mar-10	ACQ	0449346 6378692	Boundary Road	0640	FRTBC	8 roost-short; part of a larger assemblage in the area
19-Mar-10	ACQ	0449327 6374202	Boundary Road	0710	FRTBC	3 roost-short
19-Mar-10	HOT 18	0442088 6371243	Hotham Farms	1500	Baud	2 roost-rest

Appendix 2: Results of post-felling inspections of trees identified as having potentially-suitable hollows during ground-based surveys (GBS) from Finn et al. (2011).

Percentages in column 1 are relative to the overall number of trees identified (i.e. *n* = 149); percentages in columns 2 relative to column 1 (i.e. species-specific totals for trees identified); and percentages in columns 4 and 5 relative to column 3 (i.e. species-specific totals for trees with hollows intact after felling).

Tree species	1 Identified during GBS	2 Damaged in felling	3 Intact after felling	4 Large hollow present	5 Large hollow absent
Jarrah	110 (73.8%)	21 (19.1%)	89	28 (31.5%)	61 (68.6%)
Marri	26 (17.4%)	8 (30.8%)	18	10 (55.6%)	8 (44.4%)
Wandoo	13 (8.7%)	1 (7.7%)	12	8 (66.7%)	4 (33.3%)
Total	149	30	119	46 (38.7%)	73 (61.3%)

Appendix 3: Distribution of potential black-cockatoo hollows by tree species across four landscape positions within native forest sites sampled within NBG tenements and within the land exchange area from Biggs (2008)

n = 6 sites with 1 transect per landscape position at each site

	Tree Species		
Landscape Position	*Jarrah*	*Marri*	*Wandoo*
TOTAL	33	5	6
Woodland (valley floor)	4	1	6
Lower Slope	12	2	0
Upper Slope	10	0	0
Ridgetop	7	2	0

Appendix 4: Estimates of potential black-cockatoo hollows based on 'large' hollow proportions [Biggs (2008)]

6620 m total transect length (all transects combined) x 50 m transect width = 331 000 m^2 (0.331 km^2)

Jarrah:

n = 33 potential black-cockatoo hollows observed during ground-based observations along transects

33 trees observed x 0.315 large hollow proportion = **10.4 trees with 'large' hollows**

10.4 trees / 0.331 km^2 = 31.4 trees per km^2 (/100) = **0.314 trees with 'large' hollows per ha**

Marri:

n = 5 potential black-cockatoo hollows observed during ground-based observations along transects

5 trees observed x 0.556 large hollow proportion = **2.8 trees with 'large' hollows**

2.8 trees / 0.331 km^2 = 8.4 trees per km^2 (/100) = **0.084 trees with 'large' hollows per ha**

Wandoo:

n = 6 potential black-cockatoo hollows observed during ground-based observations along transects

6 trees observed x 0.667 large hollow proportion = **4.0 trees with 'large' hollows**

4.0 trees / 0.331 km^2 = 12.1 trees per km^2 (/100) = **0.121 trees with 'large' hollows per ha**