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Characteristics of Marri (*Corymbia calophylla*) fruits in relation to the foraging behaviour of the Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*)

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Abstract

Forest Red-tailed Black Cockatoos (*Calyptorhynchus banksii naso*) feed predominantly on seeds of the eucalypt Marri (*Corymbia calophylla*) and often only from specific feed trees. There was no difference between wet weight of fruits from feed (24.1 ± 1.72 g) and non-feed trees (23.2 ± 1.57 g), but trees from which Forest Red-tailed Black Cockatoos fed had a significantly higher seed number per fruit (3.9 ± 0.18), a greater individual dry seed weight (0.10 ± 0.003 g) and total seed weight per fruit (0.39 ± 0.02 g), and a higher ratio of total seed dry weight to fruit wet weight (0.02 ± 0.001) compared with non-feed trees (3.1 ± 0.20 seeds per fruit; 0.09 ± 0.005 g individual seed dry weight; 0.29 ± 0.020 g total seed dry weight per fruit; 0.013 ± 0.001 ratio of total seed dry weight to fruit wet weight). Discriminate analysis had a limited capacity to predict Marri use by Forest Red-tailed Black Cockatoos, correctly classifying about 70 % of feed trees. Seed number and total seed mass were the best fruit characteristics for the prediction of tree type. We conclude that Forest Red-tailed Black Cockatoos selectively forage from trees with fruits that have a high seed yield, but the method by which the cockatoos select these trees is unclear.

Key words: cockatoo, marri, food selection, seeds, parrots, eucalyptus

Introduction

The Forest Red-tailed Black Cockatoo (*Calyptorhynchus banksii naso*) inhabits tall eucalypt forests of Marri (*Corymbia calophylla*), Jarrah (*Eucalyptus marginata*) and Karri (*E. diversicolor*) in the south-west of Western Australia (Saunders *et al.* 1985; Saunders & Ingram 1995; Johnstone & Kirkby 1999). The geographical distribution and abundance of this sub-species of Red-tailed Black Cockatoo is suspected to have declined over the past 50 years (Saunders & Ingram 1995); it is considered to be rare to uncommon throughout its range (Johnstone & Storr 1998; Johnstone & Kirkby 1999), and is listed as near threatened (Garnett & Crowley 2000).

The Forest Red-tailed Black Cockatoo feeds on seeds of a variety of species of native flora, including Jarrah, Karri, Blackbutt (*E. patens*), Albany Blackbutt (*E. staeri*), Common Sheoak (*Allocasuarina fraseriana*) and Snottygobble (*Persoonia longifolia*), but Marri seeds are its principal food source (Johnstone & Kirkby 1999). Flocks appear to select specific Marri trees when feeding, returning to the same tree until its food supply is exhausted and often ignoring neighbouring trees. Johnstone & Kirkby (1999) suggested that the quality of the fruit varies between trees selected and ignored by these cockatoos, and that the quality of food might limit the breeding success and long-term distribution and abundance of Forest Red-tailed Black Cockatoos. Cooper (1999) reported that the fruits of feed trees had a higher seed yield than non-feed trees. We examine here fruit characteristics (fruit mass, seeds per fruit and seed mass) to further determine differences between fruits of feed and non-feed Marri trees of the Forest Red-tailed Black Cockatoo.

Methods

Fruits from feed and non-feed Marri trees of the Forest Red-tailed Black Cockatoo were examined at Armadale, Jarrahdale and north of the North Dandalup Dam, south-east of Perth, Western Australia (31º 58’ S, 115º 51’ E), in 1999 and 2003. Feed trees were identified either by observing birds feeding from a particular tree, or by observing freshly chewed fruits scattered at the base of the tree. Non-feed trees had no fruits opened and discarded by Forest Red-tailed Black Cockatoos beneath them. Three other species of parrot also feed on these Marri fruits, Baudin’s Cockatoo (*C. baudinii*), Carnaby’s Cockatoo (*C. latirostris*) and the Red-capped Parrot (*Purpureicephalus spurius*). Each species leaves characteristic marks on discarded fruits (Cooper 1999, 2000), and so trees from which the Forest Red-tailed Black Cockatoo had been feeding could be easily identified.

Six fruits were collected from each feed tree and from the nearest non-feed tree using long-handled clippers.

We attempted to take the six fruits from different parts of each tree. Fruit wet mass, fruit length and diameter, seed number and total seed dry mass were recorded for each fruit. Seeds were dried to a constant weight at 50-70 °C in a Labmaster drying oven. Feed and non-feed comparisons were made using nested ANOVA (SPSS version 11.5), with year and tree type as fixed factors, and site as a random factor nested within year. Classificatory discriminant analysis was accomplished with *statistiXL* (v 1.1). Mean (± S.E.) values for feed and non-feed trees were calculated from the mean values for six fruits from each tree.

Results

Feed tree fruits were significantly longer ($F_{1,338} = 14.48$, $p < 0.001$) and had a greater diameter ($F_{1,338} = 11.65$, $p = 0.001$); they also had more seeds ($F_{1,337} = 24.3$, $p < 0.001$), larger seeds ($F_{1,323} = 10.2$, $p = 0.002$) and a higher total dry seed mass ($F_{1,333} = 40.4$, $p < 0.001$) than non-feed trees (Table 1). The ratio of total seed mass to fruit wet mass was also significantly higher for fruits from feed than from non-feed trees ($F_{1,335} = 46.44$, $p < 0.001$). Wet mass of the fruits did not differ significantly between feed and non-feed trees ($F_{1,335} = 3.3$, $p = 0.070$). Year of sampling did not affect the fruit length ($F_{1,29} = 2.80$, $p = 0.105$), the seed content of fruits (either seed number, $F_{1,29} = 0.45$, $p = 0.506$; individual seed mass, $F_{1,30} = 2.32$, $p = 0.139$; or total dry seed mass, $F_{1,29} = 1.69$, $p = 0.204$), or the ratio of total seed mass to fruit wet mass ($F_{1,29} = 1.89$, $p = 0.180$), but the wet mass of whole fruits ($F_{1,29} = 7.97$, $p = 0.009$) and fruit diameter ($F_{1,29} = 9.58$, $p = 0.004$) were significantly greater in 2003. All fruit and seed characteristics showed highly significant variation between sites: fruit wet mass ($F_{29,335} = 31.7$, $p < 0.001$), fruit length ($F_{29,338} = 16.21$, $p < 0.001$), fruit diameter ($F_{29,338} = 28.63$, $p < 0.001$), seed number ($F_{29,337} = 2.64$, $p < 0.001$), individual seed mass ($F_{29,323} = 2.31$, $p < 0.001$), total seed mass ($F_{29,333} = 2.92$, $p < 0.001$), and the ratio between the total seed mass to fruit wet mass ($F_{29,335} = 6.18$, $p < 0.001$).

Table 1

Characteristics of Marri fruits from trees that Forest Red-tailed Black Cockatoos use (Feed) and ignore (Non-feed). Values are mean ± standard error, n = 31, average of 6 fruits per tree. * indicates significant difference at p < 0.05.

	Feed	Non-feed
Fruit wet mass (g)	24.1 ± 1.72	23.2 ± 1.57
Seed number per fruit*	3.9 ± 0.18	3.1 ± 0.20
Individual seed dry mass (g)	0.10 ± 0.003	0.09 ± 0.005
Total seed dry mass (g) *	0.39 ± 0.018	0.29 ± 0.020
Total seed mass to fruit mass ratio *	0.02 ± 0.001	0.013 ± 0.001

Discussion

Characteristics of Marri fruits

The characteristics of Marri fruits examined in this study are generally typical of Marri fruits examined in previous studies. Gill *et al.* (1992) reported that Marri fruits contained similar numbers of seeds per fruit (3.1 ± 1.3) as found in this study (3.5 ± 0.2), while Abbott (1984) found an average of 4 seeds per fruit. These slight differences in average number of seeds per fruit are presumably due to variations in study sites and perhaps variation in Marri flowering and fruiting from year to year (Mawson 1995), although we found no differences in seed characteristics between two years. Gill *et al.* (1992) reported that Marri fruits contained a total seed weight of 0.51 ± 0.17 g per fruit compared to 0.34 (± 0.02) g in this study. Again, different localised climatic and soil conditions, and yearly variations in fruiting may account for these differences, although we found no significant difference between the two years sampled.

Two non-feed trees in this study were found to have fruits containing no seeds (classified as male fruits), as has been described previously for Marri (Carr *et al.* 1971; Mawson 1995). Marri varies with respect to the proportion of male fruits. Some trees only produce male fruits, never female fruits containing seeds (Carr *et al.* 1971); male fruits are often withered in appearance, but fruits of the male trees from this study were normal in appearance. According to Carr *et al.* (1971) male fruits have no seeds because of ovule abortion late in development. Mawson (1995) suggested that the presence of male trees meant that birds feeding on Marri need to be discerning, to avoid wasting time and energy feeding on fruits that would give no energetic return. We found that Forest Red-tailed Black Cockatoos are even more discerning, since feed and non-feed trees differ in fruit energy yield.

Feed and non-feed Marri trees

Our study supports Johnstone & Kirkby's (1999) hypothesis that there is a difference in seed characteristics between feed and non-feed Marri trees. Feed trees have a higher seed number, individual seed mass and total seed dry mass per fruit compared with non-feed trees, indicating that cockatoos select Marri trees that have fruits with a higher energy content. Marri seeds contain 22.9 kJ of combustible energy g^{-1} (Cooper *et al.* 2002). Therefore, feed trees provide 8.85 kJ $fruit^{-1}$ (0.39 g x 22.9 kJ g^{-1}; assuming that all the seeds are eaten), which is a 34% greater return than for non-feed trees (6.61 kJ $fruit^{-1}$; 0.29 g x 22.9 kJ g^{-1}).

Clout (1989) and Pepper *et al.* (2000) reported that Glossy Black Cockatoos (*C. lathami*) in New South Wales and South Australia also selected feed trees with a greater seed return than non-feed trees, when feeding on *Allocasuarina littoralis* and *A. verticillata* respectively. Feed *A. verticillata* trees for South Australian Glossy Black Cockatoos (*C. l. halmaturinus*) have 23% larger seeds, 21% more seed per cone and 13% more energy per cone than trees from which the birds did not feed (Pepper *et al.* 2000). In our study, feed Marri trees had 10% larger seeds and 25% more seeds per fruit than non-feed trees and provided Forest Red-tailed Black Cockatoos with 34% more energy per fruit than non-feed trees (2.6 times the energy difference for *A. verticillata*). This presumably reflects the large size of Marri compared to *A. verticillata* seed, and possibly a greater variation of total seed dry mass in Marri compared with *A. verticillata*. It is also possible that Forest Red-tailed Black Cockatoos are more selective feeders than South Australian Glossy Black Cockatoos.

Clout (1989) suggested that *Allocasuarina* feed trees used by Glossy Black Cockatoos had a higher ratio of seed mass to fruit mass than non-feed trees, which indicates reduced handling costs compared to energy gain. For Forest Red-tailed Black Cockatoos there was also a significant difference in the ratio of total seed mass to fruit wet mass. Therefore the cockatoos receive higher energy returns for an equivalent effort by selecting trees with higher energy yields per fruit.

Johnstone & Kirkby (1999) found that wild Forest Red-tailed Black Cockatoos take up to 2.45 minutes to remove, husk and eat the seeds from a Marri fruit. When feeding from feed trees at this rate, they would obtain 3.6 kJ min^{-1}, compared with 2.70 kJ min^{-1} from non-feed trees. The 25% greater feeding rate that Forest Red-tailed Black Cockatoos attain by selecting feed rather than non-feed trees is considerably higher than the 14% increase reported for South Australian Glossy Black Cockatoos (Pepper *et al.* 2000). This increased rate of energy acquisition from feed trees would translate into a reduced daily feeding time or an increased daily energy intake.

South Australian Glossy Black Cockatoos needed to feed for 6 h 24 min day^{-1} to meet their predicted field energy requirements of 626 kJ (Pepper *et al.* 2000). Forest Red-tailed Black Cockatoos have a predicted daily field energy requirement of 934 kJ (Cooper *et al.* 2002), so when feeding from feed trees they would require only 5 h 11 min to obtain this energy, but would require 6 h 29 min day^{-1} for non-feed trees. The ability of these cockatoos to discriminate between Marri with high and low seed yields enables them to greatly reduce their foraging time and increase their energy intake. Decreasing the time required to meet their daily energy demands is of particular importance during the breeding season when the cockatoos have to meet the additional energy requirements of a chick as well as themselves. This is particularly important because the ability to obtain sufficient food, especially when breeding, is a major factor limiting the reproductive success of cockatoos (Saunders *et al.* 1985; Johnstone & Kirkby 1999; Pepper *et al.* 2000).

Predicting Marri seed yield

How the cockatoos determine which trees have the highest seed yield is unclear. Pepper *et al.* (2000) suggest that experience may play an important role in feed tree selection for South Australian Glossy Black Cockatoos feeding on *Allocasuarina.* Visual cues may indicate the potential energy yield of cones/fruits to experienced birds. Pepper *et al.* (2000) suggested that the external morphology of *Allocasuarina* cones may indicate the internal seed content, although Clout (1989) found no difference in cone size (mass, length or width) between feed and non-feed trees. For Marri, there was no visible indication to us in either shape or colour of fruits from feed and non-feed trees. Despite this, there were measurable differences in fruit length and diameter, and seed number, individual mass and total mass, of fruits from feed and non-feed trees. However, these differences were related to site variability for all fruit and seed characteristics, and year to year variability in fruit wet mass and diameter. The flowering/fruiting cycle of Marri occurs on a three to five year cycle, with flowering and fruiting varying greatly from one year to the next (Robinson 1960; Mawson 1995; Johnstone & Kirkby 1999). A feed tree with a high fruit yield in one year requires at

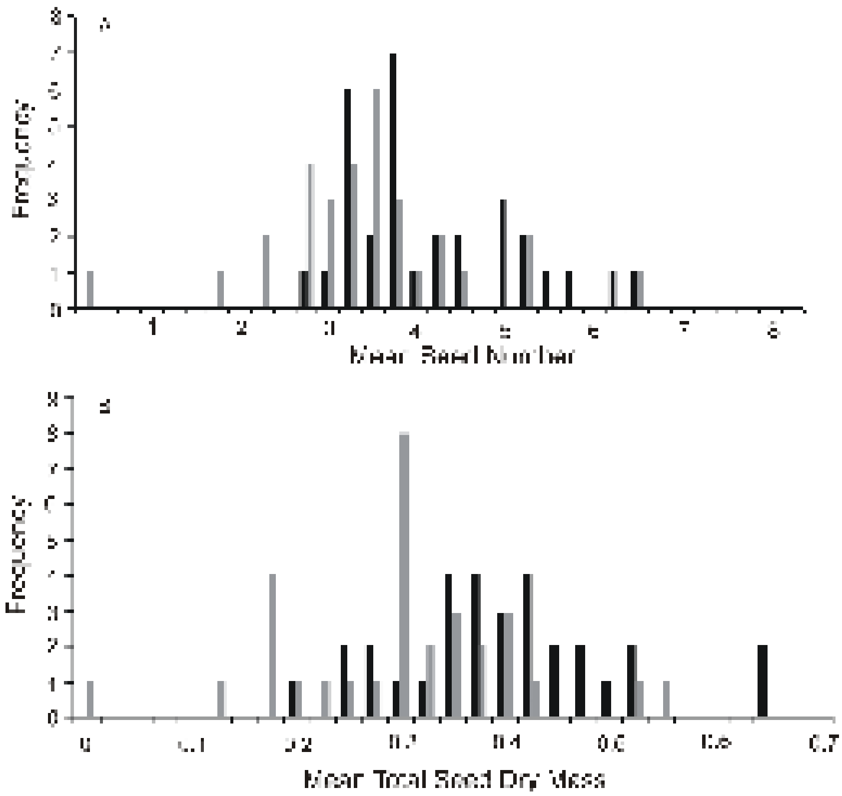

Figure 1. Frequency distribution of seed number (**A**) and total seed dry mass (g; **B**) for feed (dark bars; n = 31) and non-feed (light bars; n = 31) Marri trees (means for 6 fruits from each tree).

least three years to replenish sufficient resources to fruit successfully again (Mawson 1995; Johnstone & Kirkby 1999). Therefore, the cockatoos can't simply feed from the same trees each year; they must somehow assess the energy yield of the fruits from individual trees each time they fruit. Either they must reassess a tree each time it fruits, or remember trees with a high yield from the previous fruiting (if indeed high seed yield trees remain so in successive fruitings).

It is important for the future management of these cockatoos that we are able to predict which are feed or non-feed Marri trees. Therefore we examined the possibility of categorising feed and non-feed trees from fruit and seed characteristics, independent of site and year influences. As we measured 6 fruits per tree, we used the mean value for each characteristic for each tree to avoid pseudo-replication. There were no differences (by t-test) between feed and non-feed trees with respect to fruit wet mass ($p = 0.710$), length ($p = 0.781$), or diameter ($p = 0.652$). However, there were highly significant differences (by t-test) between feed and non-feed trees with respect to seed number ($p = 0.006$) and total seed mass ($p = 0.001$). The individual seed mass did not differ significantly ($p = 0.155$), indicating that the differences mainly reflected the number of seeds rather than their individual mass. Although it is possible on a statistical basis to distinguish samples of feed and non-feed trees, it is more difficult to categorise a single tree as feed or non-feed because there is considerable overlap in both seed number and total seed mass between feed and non-feed trees (Fig 1). A discriminant analysis for categorising fruits (using averages of 6 fruits for each tree), based on number of seeds (n) and total seed mass (m, in grams), since these were the two most useful characteristics for discrimination, yielded the following two discriminate functions;

$$F_N = 1.992\ n + 17.454\ m - 7.912$$

$$F_F = 2.040\ n + 8.622\ m - 5.096$$

These functions can be used to classify samples for a further tree by substituting its values for n and m (averages for a sample of 6 fruits); which ever function value is higher categorises the tree as feed (F_F) or non-feed (F_N). The functions correctly classified 71% of feed trees and 68% of non-feed trees. However, the practical application of the identification of potential feed trees is limited by the variability in Marri fruiting on a year to year basis (Mawson 1995). Therefore, habitat trees can't be selected due to their status as feed trees in a particular year. Further study is required to determine patterns of feed tree use over a longer period of time.

This study suggests that Forest Red-tailed Black Cockatoos select trees for a higher energy yield per fruit, and provides a method for prediction of whether a Marri is a feed or non-feed tree in any particular year. However, it is important for further studies to determine how frequently individual trees are used, and how patterns of feeding from particular trees reflect the three to five year Marri fruiting cycle. Further investigation is also required to determine the number of different feed trees used in a particular area over a longer time period, and the total number of trees used by individual flocks of Forest Red-tailed Black Cockatoos.

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