Corella, 2004, 28(3): 68–74

FOOD SOURCES OF THE RAINBOW LORIKEET *Trichoglossus haematodus* DURING THE EARLY WET SEASON ON THE URBAN FRINGE OF DARWIN, NORTHERN AUSTRALIA

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Received: 7 April 2003

The food sources of the Rainbow Lorikeet *Trichoglossus haematodus* were studied from October to January in a mixed environment of urban, semi-urban and remnant native vegetation on the coastal fringe of Darwin in the Northern Territory. The study coincided with a period of low nectar availability in the tropical savannas, but abundant flowering and fruiting of rainforest trees and the ripening of cultivated fruit of Mango *Mangifera indica.* Lorikeets obtained a diversity of food types from 37 species of plants. Consumption of seed, mostly of the Coastal She-oak *Casuarina equisetifolia*, and nectar and/or pollen from a diversity of species comprised 41 per cent and 40 per cent respectively of foraging observations. Lerp obtained from the leaves of cultivated eucalypts was also prominent in the diet, whilst consumption of fleshy fruits was minor and consisted entirely of consumption of mango early in the study period. Just over 50 per cent of flower-feeding records were at eucalypts and over 60 per cent at myrtaceous trees. Food sources and flock sizes varied considerably over time within the study period. The median size of feeding flocks was five, with a range from 1 to 30, the largest flocks occurring in Mango trees and at the flowers of woodland trees, and the smallest at cultivated flower and leaf sources. Coastal forest provided mainly seed and woodland trees mainly nectar and/or pollen, whilst the urban environment provided a wide range of resources. However, an extensive band of semi-deciduous vine-thicket provided few food sources and supported few lorikeets during the study period. The large population of lorikeets in the study area was supported both by the diversity of plants associated in particular with urban plantings, and by the juxtaposition of habitats.

INTRODUCTION

The Rainbow Lorikeet *Trichoglossus haematodus* (Psittacidae) is a successful and often abundant inhabitant of urban and other human-modified areas (Wyndham and Cannon 1985; Jones and Weineke 2000; Woodall 2002; Fitzsimons *et al.* 2003), where its bold, gregarious habits and vivid colours are a delight to many (Waterhouse 1997). In parts of Queensland, wild populations contribute significantly to the tourism industry (Cannon 1984a). However, conflict with humans may arise through depredation of crops (Templeton 1992; Lim *et al.* 1993) and the faecal deposits from urban roosts.

The role of dietary versatility in the urban success of the Rainbow Lorikeet is unclear. Although they have been recorded consuming a wide variety of foods including nectar, pollen, fleshy fruit, seeds, leaves, buds and insects (summarized in Higgins 1999), the only quantitative studies report the species to feed primarily at flowers. In mixed savanna habitat 50 kilometres south of Darwin, Franklin (1997) reported that 94 per cent of foraging observations were at flowers. In the New South Wales-Queensland border region, the percentage of foraging observations that were at flowers varied between observation periods from 68 to 100 per cent, with an overall contribution of 87 per cent (Cannon 1984b). In a qualitative urban study, Waterhouse (1997) also concluded that nectar and/or pollen were the species' major food resources, but fruits were seasonally important and supplementary feeding by humans was also recorded.

In the Top End of the Northern Territory, the early wet season is a time of low availability of nectar in the savannas that dominate the landscape (Woinarski *et al.* 2000), but in rainforest patches this is a time of substantial and increasing diversity of flowers and fruits (Bach 2002). It is also when the cultivated Mango *Mangifera indica* fruit crop ripens. *Mangifera indica* is extensively cultivated in orchards of the Darwin hinterland (Wood 2001) and as scattered trees in the urban area, and Rainbow Lorikeets are a major pest of the crop (Lim *et al.* 1993). During 1996, a roost site adjacent to an outdoor cafe in the Darwin suburb of Nightcliff was estimated to support 1 500–2 000 Rainbow Lorikeets (R. Noske, pers. comm.), prompting health concerns and the deliberate disruption of the roost. The Rainbow Lorikeet is common throughout the year in the Darwin area (Crawford 1972).

In this study, we investigate the dietary basis of the success of Rainbow Lorikeets in mixed habitat on the coastal fringe of the monsoonal tropical city of Darwin during the early wet season (October to January). Questions of particular interest include the role of food plant and habitat diversity in supporting an urban-fringe population, the extent to which nectar is important in the diet at a time of year when background availability is low, the nature of any alternative foods and the dietary contribution of mango from scattered urban plantings.

STUDY AREA

Darwin (12°28'S, 130°50'E) is a tropical city of 90 000 people on the edge of the Timor Sea in the north-west of the Northern Territory of Australia. The climate is intensely monsoonal, the mean annual rainfall of 1 650 millimetres falling almost entirely between October and April and with a particular concentration of rainfall in the three month period commencing mid-December.

The 800 hectare study area lies on the coastal northern fringe of Darwin, taking in the suburbs of Nightcliff and Rapid Creek, the mangrove flats of the Rapid Creek estuary, the Casuarina campus of Charles Darwin (Northern Territory) University and the Casuarina Coastal Reserve (Fig. 1). The suburbs of Nightcliff and Rapid Creek were established after World War II (Barter 1994). Most native vegetation has been removed, but mangroves and some coastal cliff vegetation persists. Extensive planting of exotic and native tropical species has occurred in parks and gardens including the adjacent campus of the Charles Darwin University. Nightcliff was destroyed by Cyclone Tracey in December 1974, but extensive plantings since then are now largely mature, growth being rapid in tropical conditions with supplementary water during the dry season. Casuarina Coastal Reserve was formally established in 1978. It comprises remnant stands of coastal dune forest dominated by Coastal She-oak *Casuarina equisetifolia*, semi-deciduous monsoon forest, eucalypt woodland, Broad-leaved Paperbark *Melaleuca viridiflora* swamp forest, and mangroves, along with planted trees in picnic areas. The coastal dune forest has a history of disturbance and rehabilitation (PWCNT 2002). The study area rises from the coast to an undulating plateau reaching 32 metres above sea level. Soils vary from dune and siliceous sands, often with a calcareous hardpan, through saline mud and clays at the coast and gravelly lithosols to yellow massive earths on more elevated sites.

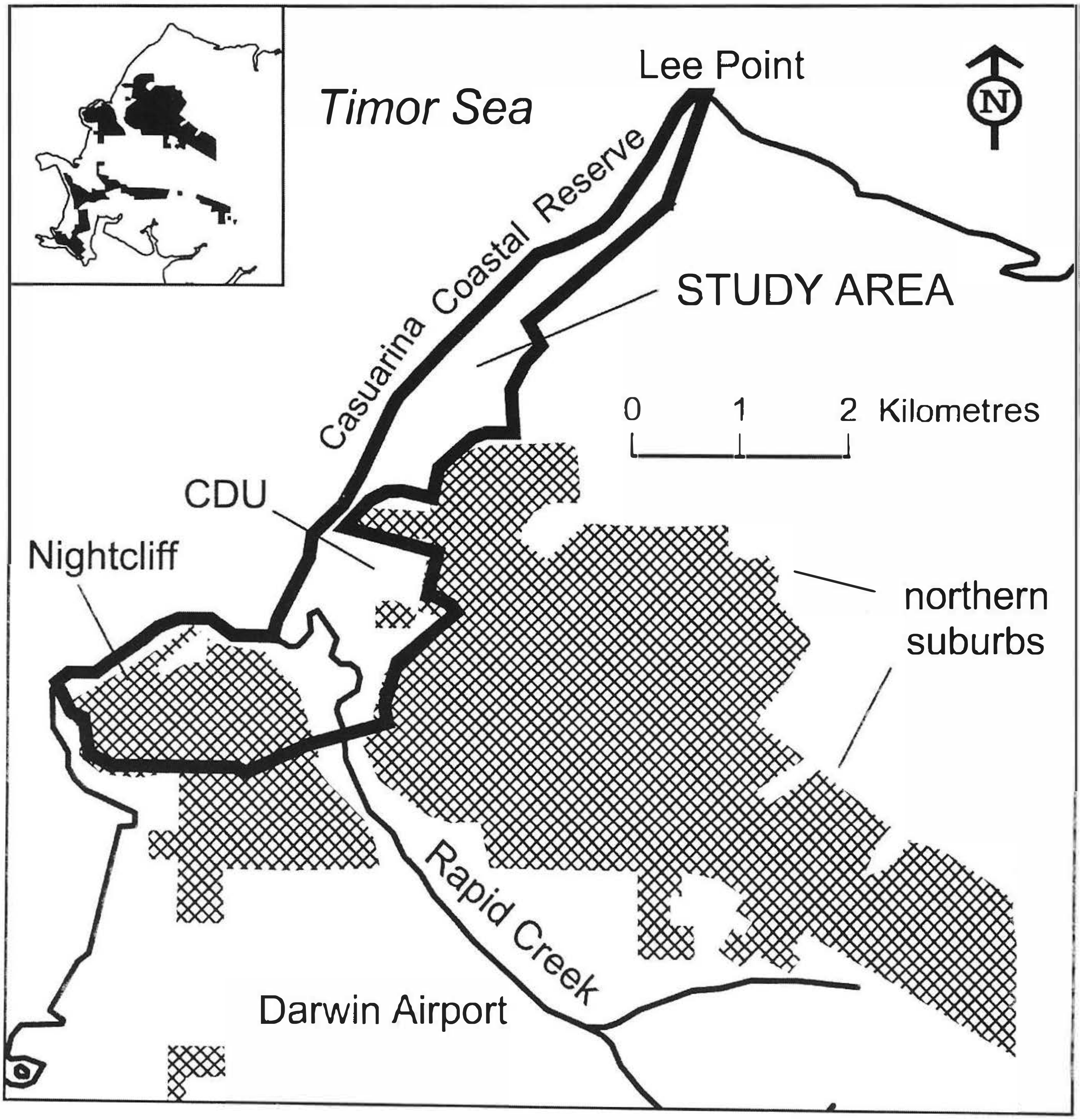

Figure 1. *Study area, with inset of the city of Darwin (dark areas are urban), Northern Territory. CDU = Charles Darwin University.*

METHODS

Data collection

A 20.1 kilometre transect was established along streets, bicycle tracks and paths through the study area. It included an estimated 8.0 kilometres of cultivated vegetation including urban areas, and 12.1 kilometres of native vegetation, including 5.4 kilometres of coastal and monsoon forest in a single large block, 1.0 kilometre of mangroves on the Rapid Creek estuary and 5.7 kilometres of eucalypt woodland with interspersed *Melaleuca* swampland divided between several locations, but there was also considerable fine-scale interspersion and intergradation of habitats.

The transect was traversed by Makoto Hasebe (MH) by bicycle at about 10 kilometres/per hour twice per week from 1 October 2002 to 28 January 2003; 18 weeks in total. For most of the study period, the traverse was divided between the early morning and late afternoon and repeated in the reverse order the following day, but late in the study period when few lorikeets were encountered, the two traverses were completed in the one day, one in the morning and the other in the afternoon. The time taken to complete the weekly field commitment varied from 4–16 hours, depending on the number of lorikeet flocks encountered. Rainbow Lorikeets were detected by sight or sound, the maximum distance of detection varying from 15 to more that 50 metres depending on the density of vegetation. When lorikeets were detected, MH stopped and checked whether they were feeding. If feeding, the food plant species, foraging substrate, food type and the size of flock were recorded before proceeding to the next encounter. Foraging substrates were categorized as flower, dry fruit, fleshy fruit, leaf or bark. A flock was defined as a group of birds feeding on one or several adjacent plants of the one species. The size of larger flocks could not always be assessed accurately because of dense foliage and movement of birds and was then estimated to the nearest multiple of five.

Analysis

Food plants were classified as naturally-occurring or cultivated, revegetated *C. equisetifolia* in Casuarina Coastal Reserve being classed as naturally-occurring. Naturally-occurring plants were further subdivided into forest and woodland species, reflecting the primary association of the species with coastal forest, monsoon forest or mangroves (forest) or the eucalypt/*Melaleuca* savanna matrix (woodland). Cultivated species were classed as Australian natives or exotics.

For analysis of foraging substrates, leaf and bark were combined because of small sample size of the latter. Because flock size could not always be established accurately, analyses of flock sizes are non-parametric. The diversity index for food sources (species/substrate combinations) was calculated using the Shannon-Wiener function with base 10 logarithms (Krebs 1989).

RESULTS

Over the 18 week study period, 1 311 observations of feeding flocks containing an estimated 7 210 Rainbow Lorikeets were recorded, an average of 73 flocks and 401 individuals per week. There was considerable fluctuation in numbers from week to week and a marked decline towards the end of the study period (Fig. 2a).

Diet, food plants and habitats

Seeds and nectar and/or pollen were the most important dietary items, followed by lerp and distantly by fruit and occasional other items obtained from bark and leaves (Table 1).

Food was obtained from 37 plant species and 44 species/substrate combinations (Table 2), but only two species/substrates contributed more than 10 per cent of observations, four more than 5 per cent of observations and 13 more than 1 per cent of observations. Seeds were obtained mostly by extraction from the woody cones of *C. equisetifolia*, lerp from the leaves of cultivated *Eucalyptus camaldulensis* and fruit entirely from *M. indica*, and a wide range of plants contributed nectar and/or pollen. Myrtaceous trees provided the majority of flower-foraging records in all habitats, but the generic contribution varied between habitats, eucalypts (*Eucalyptus* and *Corymbia*) and *Melaleuca* occurring in the woodland and cultivated habitats and *Syzygium* mostly in forest habitats (Table 3). Six species provided more than one foraging substrate, of which the most substantial contribution was from cultivated *E. camaldulensis*, from which lorikeets obtained lerp from leaves, nectar/pollen from flowers and unknown items from bark.

Cultivated vegetation provided far more food plant species (Table 1) and a wider dispersion of substrates (Table 4) than did the forest and woodland plants, but a little less than half of all foraging records (Table 1). All records of fruit consumption, and most leaf and bark foraging, were from cultivated vegetation. The majority of cultivated species were natives of the Top End (Table 2). Forest plants provided predominantly seed (from *C. equisetifolia*) and woodlands predominantly flowers (Table 4). Amongst forest plants, most foraging was in the coastal dune forest, with mangroves contributing just one food plant species (White-flowered Black Mangrove *Lumnitzera racemosa*) and 0.2 per cent of foraging records. Although a number of rainforest species provided food, notably the tree Black Apple *Syzygium nervosum*, most foraging on this category of plant was from scattered plants in the dune forest rather than in the semi-deciduous vine-thicket.

Flock size

The median flock size was five, with a range from one to 30. Flock size varied significantly between habitat/substrate classes for which there were 10 or more records (Table 4, 8 classes, n = 1 305; Kruskal-Wallis H = 106.7, $P < 0.001$). Median flock size was particularly large for forest flowers and cultivated fruits, and particularly small for cultivated seed sources and cultivated leaf/bark sources.

Change over time

There was significant variation among weeks in the Rainbow Lorikeet's use of habitats (Fig. 2b; Chi-square = 208.7, d.f. = 34, $P < 0.001$) and substrates (Fig. 2c; Chi-square = 293.2, d.f. = 51, $P < 0.001$), and also in flock size (Kruskal-Wallis H = 144.6, $P < 0.001$). Forest and cultivated plants, and also seeds and flowers, were used throughout the study period. Fleshy fruit (i.e. mango) was not used after mid-November, and leaf/bark substrates rarely after early December (Fig. 2c).

Only one species/substrate combination, the seeds of *Casuarina equisetifolia*, was used by Rainbow Lorikeets in all weeks of the study period (Table 2), with use exceeding 20 flocks in 13 of 18 weeks and peak use (>50 flocks per week) in late November and early December. Other species/substrate combinations used by more than 20 flocks in a week were: cultivated *E. camaldulensis*

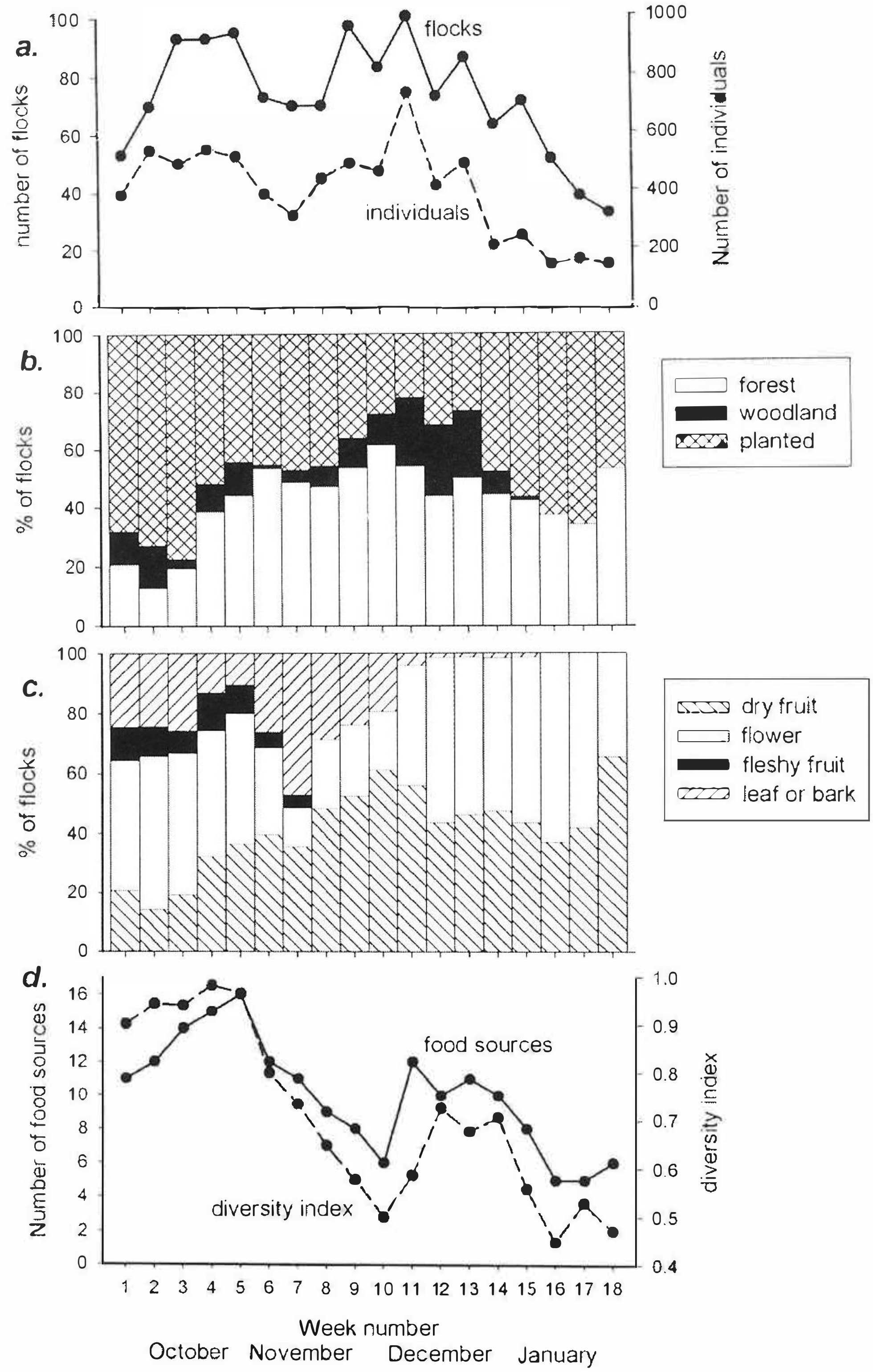

Figure 2. *Variation over time in the numbers and foraging behaviour of Rainbow Lorikeets: a. numbers of flocks and individuals; b. use of habitats; c. use of substrates; and d. the number and diversity of food sources (species/substrate combinations).*

TABLE 1

Proportion of Rainbow Lorikeet flocks (n = 1 311) observed feeding on different substrates and in different habitat classes, together with the number of plant species being used in each class. The total number of plant species is less than the sum of the classes because some species provided more than one foraging substrate and were used both in the natural and cultivated state.

	% of flocks	No. of plant species
SUBSTRATE — FOOD TYPES		
dry fruit — seed	41.1	4
flowers — nectar/pollen	40.4	32
leaves — mostly lerp, some unknown	14.3	5
fleshy fruit — fruit	3.7	1
bark — unknown	0.6	2
HABITAT		
forest	42.8	7
woodland	10.3	4
cultivated	46.9	29
TOTAL		37

TABLE 2

Food plants, foraging substrates and food types used by the Rainbow Lorikeet. Occurrence: NF = naturally occurring, forest; NW = naturally occurring, woodland; CN = cultivated Australian native (* indicates native to the Top End of the Northern Territory); CE = cultivated exotic; CU = cultivated, of unknown origin.

Species	Family	Occurrence	Substrate	Food type	Flocks No.	Flocks %	Weeks used (n)
Casuarina equisetifolia	Casuarinaceae	NF and CN*	dry fruit	seed	520	39.7	18
Eucalyptus camaldulensis	Myrtaceae	CN*	leaf	lerp	175	13.3	12
Corymbia bella	Myrtaceae	NW and CN*	flower	nectar/pollen	118	9.0	14
Corymbia ptychocarpa	Myrtaceae	CN*	flower	nectar/pollen	101	7.7	7
Eucalyptus camaldulensis	Myrtaceae	CN*	flower	nectar/pollen	54	4.1	7
Melaleuca viridiflora	Myrtaceae	NW and CN*	flower	nectar/pollen	51	3.9	12
Mangifera indica	Anacardiaceae	CE	fleshy fruit	fruit	48	3.7	7
Schefflera actinophylla	Araliaceae	CN*	flower	nectar/pollen	34	2.6	15
Peltophorum pterocarpum	Caesalpiniaceae	CN*	flower	nectar/pollen	31	2.4	7
Syzygium nervosum	Myrtaceae	NF	flower	nectar/pollen	24	1.8	4
Khaya senegalensis	Meliaceae	CE	flower	nectar/pollen	22	1.7	8
Tamarindus indica	Caesalpiniaceae	CE	flower	nectar/pollen	19	1.4	7
Acacia auriculiformis	Mimosaceae	NF	dry fruit	seed	17	1.3	6
Calophyllum inophyllum	Clusiaceae	CN*	flower	nectar/pollen	12	0.9	7
Terminalia ferdinandiana	Combretaceae	NW	flower	nectar/pollen	10	0.8	2
Pongamia pinnata	Fabaceae	NF	leaf	leaf	9	0.7	2
Pterocarpus indicus	Fabaceae	CE	flower	nectar/pollen	8	0.6	3
Unknown 1		PU	flower	nectar/pollen	7	0.5	3
Cocos nucifera	Arecaceae	CE	flower	nectar/pollen	5	0.4	3
Corymbia bella	Myrtaceae	NW and CN*	bark	unknown	5	0.4	5
Cassia fistula	Caesalpiniaceae	CE	flower	nectar/pollen	4	0.3	3
Pongamia pinnata	Fabaceae	NF	flower	nectar/pollen	4	0.3	2
Albizia lebbeck	Mimosaceae	CN*	flower	nectar/pollen	3	0.2	2
Lumnitzera racemosa	Combretaceae	NF	flower	nectar/pollen	3	0.2	2
Melaleuca argentea	Myrtaceae	CN*	flower	nectar/pollen	3	0.2	2
Syzygium armstrongii	Myrtaceae	CN*	flower	nectar/pollen	3	0.2	2
Melaleuca leucadendra	Myrtaceae	CN*	flower	nectar/pollen	2	0.2	2
Melaleuca viridiflora	Myrtaceae	NW	bark	unknown	2	0.2	2
Unknown 2		NF	flower	nectar/pollen	2	0.2	1
Acacia holosericea	Mimosaceae	CN*	dry fruit	seed	1	0.1	1
Cocos nucifera	Arecaceae	CE	leaf	unknown	1	0.1	1
Eucalyptus bigalerita	Myrtaceae	CN*	flower	nectar/pollen	1	0.1	1
Eucalyptus bigalerita	Myrtaceae	CN*	leaf	lerp	1	0.1	1
Eucalyptus camaldulensis	Myrtaceae	CN*	bark	unknown	1	0.1	1
Eucalyptus tetrodonta	Myrtaceae	NW	dry fruit	seed	1	0.1	1
Eucalyptus sp.	Myrtaceae	CN	flower	nectar/pollen	1	0.1	1
Hibiscus tiliaceus	Malvaceae	NF	leaf	unknown	1	0.1	1
Khaya sp.	Meliaceae	CE	flower	nectar/pollen	1	0.1	1
Maranthes corymbosa	Chrysobalanaceae	CN*	flower	nectar/pollen	1	0.1	1
Unknown 3		CU	flower	nectar/pollen	1	0.1	1
Unknown 4		CU	flower	nectar/pollen	1	0.1	1
Unknown 5		CU	flower	nectar/pollen	1	0.1	1
Unknown 6		CU	flower	nectar/pollen	1	0.1	1
Unknown 7		CU	flower	nectar/pollen	1	0.1	1
Total					1 311	100.0	

TABLE 3

Contribution of myrtaceous genera to flower-foraging, by habitat. All Myrtaceous genera used are listed. Percentages are of all flower-foraging records in that habitat.

Genus	Total	Habitat: Forest	Habitat: Woodland	Habitat: Cultivated
Eucalyptus + Corymbia	52%	0	72%	50%
Melaleuca	11%	0	20%	8%
Syzygium	5%	73%	0	1%
All Myrtaceae	67%	73%	92%	59%
n (all flower sources)	529	33	129	367

TABLE 4

Use of and flock size at substrates by habitats. Data for each category are: % of all foraging records (n = 1311); median flock size; 10th and 90th percentile of flock sizes (for n > 9 only).

Substrate/food type	Habitat: Forest		Habitat: Woodland		Habitat: Cultivated		Total	
Dry fruit/seed	40%	5 2–10	0.1%	6	2%	2.5 1–15	41%	5 2–10
Flowers/nectar/pollen	3%	9 4–15	10%	5 2–12	28%	4 1–10	40%	5 2–10
Fleshy fruit	0		0		4%	7 3–20	4%	7 3–20
Leaves/bark/lerp and unknown	1%	4.5 3–16	0.4%	2	14%	3.5 2–8	15%	4 2–8
Total	43%	5 2–10	10%	5 2–12	47%	4 1–10	100%	5 2–10

leaves in three weeks, woodland and cultivated Ghost Gum *Corymbia bella* flowers in two weeks and cultivated Spring Bloodwood *Corymbia ptychocarpa* in two weeks. Of the 184 food source/week (species/substrate/week) combinations, the median number of flocks was three, with 79 per cent of combinations comprising 10 or less flocks. The number of food sources used in a week ranged from five to 16, with a median of 10.5 and peak values (>12) for three successive weeks in late October (Fig. 2d).

DISCUSSION

Diet

This is the first quantitative study of the food sources of the Rainbow Lorikeet in which flowers were not the major foraging substrate. Seeds of *Casuarina*, the single most important food item in this study, were a minor component of the diet in the studies of Cannon (1984b) and Waterhouse (1997). However, Bell (1966) described substantial episodes of foraging by Rainbow Lorikeets on the seeds of *C. equisetifolia*, with the season extending from September to late March, a period entirely embracing that reported here. Lepschi (1993) also reported *C. equisetifolia* seed as a dietary item for the Rainbow Lorikeet.

As in other quantitative studies (Cannon 1984b; Franklin 1997; see also Brooker *et al.* 1990; Waterhouse 1997), eucalypts featured prominently amongst plants providing flowers as foraging substrates, a pattern that seems to hold whether the flower sources are cultivated or of natural occurrence. In this study, it was unclear whether nectar or pollen was obtained from flowers, but previous reports (reviewed in Higgins 1999) suggest that Rainbow Lorikeets mainly consume nectar and pollen much less frequently.

A little over 13 per cent of foraging records were of lerp obtained from the leaves of cultivated eucalypts. Lerp are the sugary sections of psyllid insects (Yen 1983). The only previous record of lerp in the diet of the Rainbow Lorikeet is a report by Lord (1955) of sugary material obtained from scale insects. However, it is surprising that there are not more records, as the simple carbohydrate structure of lerp provides a ready substitute for nectar in the diet of a range of creatures including other lorikeets (Higgins 1999), honeyeaters (Paton 1980), pardalotes (Woinarski 1985) and flying-foxes (Law and Lean 1992).

Just under 4 per cent of foraging records in this study were of (fleshy) fruit, but all were of mango. The absence of feeding records from other fruit sources is surprising given that the study area included a substantial area of vine-thicket, the study coincided with the fruiting season of many vine-thicket plants (Bach 2002), and a range of vine-thicket plants were observed in fruit (MH, pers. obs.).

The Rainbow Lorikeet and the urban fringe environment

The large number of foraging records obtained during this study indicates a dense population of the Rainbow Lorikeet in an environment that was clearly favourable during the study period. The breeding season of the Rainbow Lorikeet in the Top End is unclear but is probably in the dry season prior to the study period (MH and DCF (Donald C. Franklin), pers. obs.), and no evidence of breeding was noted during this study. The sharp decline in the population along our transect during January coincides with the onset of major flowering by *M. viridiflora* (Franklin and Noske 1998), a notable stand of which at Marrara Swamp 6 kilometres south-east of the study area was indeed noted flowering heavily in January 2003 (DCF, pers. obs.).

The urban fringe environment provided a considerable variety of food types and food plant species for the Rainbow Lorikeet, as well as one (*C. equisetifolia*) that was available throughout the study period. Much of the diversity was contributed by cultivated plants, although the combined contribution of forest and woodland environments as measured by the number of foraging records and the size of flocks was greater overall. Of note is that almost all foraging at woodland plants was at flowers, a result consistent with the data of Franklin (1997) obtained 50 kilometres away in woodland during the dry season.

A limitation of the urban environment for the Rainbow Lorikeet is that the food plants available at any particular time are frequently isolated individuals, whereas in natural environments tree species often occur in extensive stands. This difference was reflected in flock sizes, which were generally smaller at cultivated food sources (*M. indica* fruit notably excepted) than those of the forest and woodland. Thus, urban and natural environments are complementary in not only the species composition and types of food resources they provide, but also the spatial scale of its availability. This complementarity is undoubtedly a major contributing factor to the dense population of Rainbow Lorikeets in the study area. The variability of the diet from week to week further emphasizes the value of the proximity of these environments.

Humans, mangoes and the Rainbow Lorikeet

In a survey of grower's perceptions, Lim *et al.* (1993) found that depredation of mangoes by winged vertebrates in the Northern Territory peaked with their ripening in October and November, consistent with the timing of our observations. The Rainbow Lorikeet was regarded as second only to the Black Flying-fox *Pteropus alecto* as the cause of this depredation. Our study was not conducted in an orchard area, but *M. indica* was present as scattered individuals throughout the urban portion of the study area. Notwithstanding this, the median Rainbow Lorikeet flock size at *M indica* was particularly large, suggesting either a preference for the species, or perhaps more simply that the resources available from a single tree at any particular time were particularly large.

Use of *M. indica* by the Rainbow Lorikeet coincided with the peak in the variety of food resources, with much of that variety concentrated amongst planted species, and mangoes were only ever a small portion of the diet. Given the considerable extent of *M. indica* orchards in the Darwin area, it is unlikely that quantity of food for the Rainbow Lorikeet in orchard areas are limiting when fruit are ripening. A management option worthy of further investigation would be trials to identify preference; if food sources other than mangoes are preferred, then companion planting might prove successful. The success of tourism centred on the Rainbow Lorikeet in other regions (Cannon 1984a) suggests a more positive and economically-supportable basis for living with Rainbow Lorikeet roosts in Darwin.

ACKNOWLEDGMENTS

Penny Wurm facilitated many aspects of the project, and Dan McIntyre prepared the map. Peter Whitehead and Guy Pardon commented helpfully on a draft.

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