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Diet of the Satin Bowerbird *Ptilonorhynchus violaceus* in the Illawarra Region, New South Wales, Australia

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Phenological patterns in fruiting are an important facet of avian frugivore ecology. The annual diet of the Satin Bowerbird *Ptilonorhynchus violaceus* has been documented mainly in the northern parts of its distribution. Less diverse assemblages of fruiting plants are expected in the more temperate regions. This paper reports on a five-year dietary study in the Illawarra rainforests, south of Sydney. Ground surveys recorded monthly phenologies for 83 species of fleshy fruit-producing plants and 78 observations of Satin Bowerbirds feeding. Twenty-six species of trees and climbers were identified in the diet. Moreton Bay Fig *Ficus macrophylla*, Jackwood *Cryptocarya glaucescens* and Crabapple *Schizomeria ovata* were the most significant feed species, followed by Wild Quince *Alectryon subcinereus*, White Quandong *Elaeocarpus kirtonii*, Sandpaper Fig *Ficus coronata* and Brown Beech *Pennantia cunninghamii*. Species that fruited sporadically comprised approximately one-third of the fruit component of the diet. The number of species fruiting reliably was lower during the breeding season, from September to December, than other months of the year. During this period, there appears to be accentuated reliance on invertebrate prey and herbs. Satin Bowerbirds formed foraging associations with seven other birds, sharing more than half of the fruit species in its diet. This study contributes ecological information necessary for restoring natural corridors in the fragmented Illawarra rainforests to facilitate fauna movement and seed dispersion.

INTRODUCTION

Avian frugivory has been well-studied (Church 1997; McCarty *et al.* 2002; Neilan *et al.* 2006), owing to prospects of the important role frugivores play in maintaining fragmented forest landscapes (Price 2006). Phenological patterns in fruit resources have a large influence on the ecology of frugivores (Price 2004), forcing species to be highly mobile or able to exploit other food items in certain times of the year. Specificity between fruiting plants and their seed dispersers is one of the most-studied aspects of avian frugivory (Sallabanks and Courtney 1993; Brown and Hopkins 2002). Obligate frugivory is uncommon, owing to a lack of consistent year-round fruit resource and insufficient protein in fruit to fulfil dietary needs (White 1974; Berthold 1976; Mattson 1980; Snow 1981; Thomas 1984; Jordano 1992; Pryor *et al.* 2001).

The Satin Bowerbird *Ptilonorhynchus violaceus* is a common passerine of eastern Australia (Frith and Frith 2004; Rowland 2008), distinctive for its glossy satin plumage in males and striking green pattern in females, as well as its bower (Vellenga 1970; Borgia 1985). Bowers are often decorated with ornaments such as various plant materials, fungi, lichen, invertebrate exoskeletons and feathers, as well as non-natural items such as straws, bottle tops and pegs (Marshall 1932, 1954; Vellenga 1970; Higgins *et al.* 2006; Wojcieszek *et al.* 2007). Satin Bowerbirds occur in two disjunct populations: from eastern Victoria north to Kroombit Tops, Queensland, and in the Atherton Region between Paluma and Mount Amos, Queensland (Higgins *et al.* 2006). Suitable habitat is mainly found in rainforests and wet sclerophyll forests (Schodde and

Mason 1999; Frith and Frith 2004, 2005), however drier forests, woodlands and modified habitats are also adequate (Gregory-Smith 1991; Wood 1998; Fulton 2002; Higgins *et al.* 2006).

Bowerbirds forage at all heights from the ground to the canopy (Donaghey 1981; Goddard 1999; Rose 1999). Detailed dietary studies have been largely confined to the northern parts of its distribution (Donaghey 1981; Church 1997; Higgins *et al.* 2006). The diet consists of fruits, flowers, nectar, seeds and leaves, including exotic weeds (Donaghey 1981; Gosper 1999; Holland 2000; Conole 2004; Rowland 2008). In one study in the northern New South Wales (NSW), fruit comprised 67 percent of the annual diet and the most significant component for eight months in rainforest sites; whereas for woodland sites, fruit was important for only six months (Donaghey 1981). There are also observations of bowerbirds grazing on herbs (Donaghey 1981; Goddard 1999) and obtaining sap from a tree scar formed by Yellow-bellied Gliders *Petaurus australis* (Chapman *et al.* 1999). Invertebrates are also taken (Nubling 1921; Donaghey 1981), as are nestlings of other birds (Bell 1960). Bowerbirds exploit human habitation and can be considered a pest in gardens and cropping operations (Chaffer 1984; Holland 2000; Wilson 2000).

This paper reports on a dietary study of the Satin Bowerbird in Illawarra rainforests, south of Sydney, part of a wider investigation on avian frugivory (Waterhouse 1995, 2001; Mo and Waterhouse, unpub. data). The aims of the study were:

1. To determine the monthly phenology of the fleshy fruit-producing plants available to the Satin Bowerbird in the Illawarra rainforests

2. To identify the fruit species and other food items of the local Satin Bowerbird diet, and understand the seasonal importance of various dietary components
3. To provide evidence of commensalism with other frugivorous avifauna

From a management perspective, these findings on local dietary requirements provide an important resource as no similar studies on the Satin Bowerbird have been carried out as far south as the Illawarra rainforests. Considering severe habitat fragmentation in the region, this study provides a basis for assessing the extent of habitat connectivity for local populations.

METHODS

Study area

The main study sites were Mount Keira (34°24'S, 150°51'E) and Bulli Mountain (34°20'S, 150°54'E), both sections of the Illawarra Escarpment State Conservation Area, managed by the NSW National Parks and Wildlife Service. These sites were visited twice per month for one-day visits between January 1988 and December 1992. A total of 132 field days were undertaken.

Further to the routine surveys, four additional sites were included in the study to broaden the geographical coverage of observations. One site, Bola Creek in the Royal National Park (34°9'S, 151°1'E), is located north of the routine sites. The others are located further south: Minnamurra Falls in Budderoo National Park (34°38'S, 150°43'E), Saddleback Mountain (34°41'S, 150°47'E) and Foxground (34°43'S, 150°46'E). These sites were visited up to four times per year; at least once per season.

During the study period, mean day temperatures were between 8°C (August) and 25°C (January) (Australian Bureau of Meteorology, Wollongong University Station, 1988–1992). High rainfall usually occurred in February, April and June. The area received 1726 millimetres in mean annual rainfall between 1988 and 1992.

Data collection

Observations of Satin Bowerbirds were made by moving slowly along walking tracks and inspecting forested areas from scenic lookouts and cleared recreational areas. Mount Keira was surveyed from Robertson's Lookout, the Mount Keira Scout Camp, Byarong Park, the Mount Keira Ring Track (length ~ 5.5 km) and the Dave Walsh's Track (length ~ 800 m). Bulli Mountain was surveyed from Bulli Lookout and a walking track that leads to Sublime Point (length ~ 2.5 km). Bowerbirds were often heard calling from a distance, which provided two advantages. An observer could begin to sight the birds before approaching them, hence determine what they were feeding on before they became disturbed. Also, an observer could locate birds feeding just outside the visual range of walking tracks. Binoculars were used to optimise observations and were essential for identifying non-fruit food items.

Phenological data on fruiting plants were gathered during the surveys, and organised into a monthly database. The scope of fruiting plants investigated was limited to species that produced fleshy fruit. The length of months each species produced fruit

were defined as their crop period. Species were considered to fruit reliably in a particular month if crop was produced in more than 50 percent of years. A core crop period (CCP), based on the length of months fruiting occurred reliably on an annual basis, was then determined for each species.

RESULTS

A total of 78 feeding observations of Satin Bowerbirds was recorded. Most feeding observations occurred in the months of January, March, May and September, these data comprising approximately 14, 27, nine and 10 percent of the total dataset respectively. In all other months, less than eight feeding observations were accumulated over the entire study period.

Fruit component of the diet

Of 83 species of fruiting plants available, Satin Bowerbirds were observed feeding on 26 species (Table 1). Moreton Bay Fig *Ficus macrophylla*, Jackwood *Cryptocarya glaucescens* and Crabapple *Schizomeria ovata* were significant in the diet, all of which fruited reliably in the early part of the year: Moreton Bay Fig from January to March, Jackwood from April to May, and Crabapple from February to March. A further four species were also moderately used: Wild Quince *Alectryon subcinereus*, White Quandong *Elaeocarpus kirtonii*, Sandpaper Fig *Ficus coronata* and Brown Beech *Pennantia cunninghamii*. CCP for these species include a broader section of the year, most notably Wild Quince, from June to October, and Brown Beech, from November to December. White Quandong produced crop sporadically, with fruits observed only between December 1989 and February 1990. Nonetheless, bowerbirds exploited its fruits during this limited period.

Of species in the diet, the availability of species in CCP varied considerably throughout the year. Maximum overlaps in CCP occurred in April, during which eight species fruiting reliably were available. The months of February, March and June were similar, with six species producing crop reliably. The least number of species fruiting reliably at a time were recorded between October and December; Wild Quince was the only CCP species available in October, and Brown Beech was the only CCP species available in November and December.

Feeding of dependent fledglings was seen only twice, in the autumn of 1988. In both cases, the fledgling sat motionless on a perch and waited for food to be delivered by its parent. Female bowerbirds were observed bringing the fruits of Moreton Bay and Sandpaper Figs to fledglings.

Other components of the diet

This study only gathered a few observations of bowerbirds preying on invertebrates, though they do offer further insight on feeding behaviour:

- September 1988 – a bowerbird flew up from a branch above the canopy and captured a winged ant (order Hymenoptera) in mid-air
- October 1989 – a bowerbird picked Bogong Moths *Agrotis infusa* off the undersurface of leaves in the foliage of tall eucalypt trees

Table 1 (Continued)

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| CLIMBERS | | | | | | | | | | | | |
| Gum Vine <i>Aphanopetalum resinosum</i> | | | | | | | | | | | | |
| White Moth Vine <i>Araujia sericifera</i> * | | | | | | | | | | | | |
| Staff Vine <i>Celastrus subspicatus</i> | | | | 2 | 1 | | | | | | | |
| Kangaroo Vine <i>Cissus antarctica</i> | | | 1 | | | | 1 | 1 | 1 | | | |
| Water Vine <i>Cissus hypoglauca</i> | | | 1 | | | 1 | | 1 | | | | |
| Toothed Clematis <i>Clematis aristata</i> | | | | | | | | | | | | |
| Wombat Berry <i>Eustrephus latifolius</i> | | | | | | | | | | | | |
| Scrambling Lily <i>Geitonoplesium cymosum</i> | | | | | | | | | | | | |
| Round-leaf Vine <i>Legnephora moorei</i> | | | | | | | | | | | | |
| Milk Vine <i>Marsdenia rostrata</i> | | | | | | | | | | | | |
| Southern Melodinus <i>Melodinus australis</i> | | | | | | | | | | | | |
| Jasmine Morinda <i>Morinda jasminoides</i> | | | | | 2 | | | | | | | |
| Anchor Vine <i>Palmeria scandens</i> | | | 1 | | | | | | | | | |
| Wonga-wonga Vine <i>Pandorea pandorana</i> | | | | | | | | | | | | |
| Common Silkpod <i>Parsonia straminea</i> | | | | | | | | | | | | |
| Pepper Vine <i>Piper novaehollandiae</i> | | 2 | | | | | | | | | | |
| Broad-leaved Bramble <i>Rubus moluccanus</i> | | | | | | | | | | | | |
| Bush Lawyer <i>Rubus nebulosus</i> | | | | | | | | | | | | |
| Native Raspberry <i>Rubus parvifolius</i> | | | | | | | | | | | | |
| Elmleaf Blackberry <i>Rubus ulmifolius</i> * | | 1 | | | | | | | | | | |
| False Sarsaparilla <i>Smilax australis</i> | | | | | | | | | | | | |
| Snake Vine <i>Stephania japonica</i> | | | | | | | | | | | | |
| HERBS | | | | | | | | | | | | |
| Black-fruit Saw-sedge <i>Gahnia melanocarpa</i> | | | | | | | | | | | | |
| Settlers Flax <i>Gymnostachys anceps</i> | | | | | | | | | | | | |
| Inkweed <i>Phytolacca octandra</i> * | | | | | | | | | | | | |

*indicates an introduced species

- December 1989 – a bowerbird was observed carrying a beetle (order Coleoptera) in its bill, tilting its head backwards to swallow
- December 1990 – a bowerbird chased and captured a cicada (order Hemiptera), then flew away with it in its bill
- March 1992 – after recent rainfall, a bowerbird foraged on the lawns of the Mount Keira Scout Camp and eventually pulled out an earthworm (order Megadrilacea) from beneath the grass

Grazing on a manicured lawn for periods of up to 10 minutes was observed in the month of September from 1988 to 1990. Bowerbirds were also seen feeding off herbs, later identified as Plantain *Plantago* spp., Cobbler's Pegs *Bidens pilosa* and Scarlet Pimpernel *Anagallis arvensis*, growing on a gravel road in May 1988 and September 1989. These observations were brief and distant; consequently whether the bowerbirds were consuming one of these species or invertebrates dwelling on them was not confirmed.

Non-natural foods

A number of non-natural foods were taken, including cultivated fruits (R. Jordan, D. Walsh and A. Ring, pers. comm). The extent of bowerbird damage was variable; all fruits could be taken from one property in some seasons, while none were taken in other seasons. Oranges were only exploited in winter (A. Ring, pers. comm). Despite the use of bird netting, bowerbirds were able to gain access from small openings. They also destroyed young seedlings, and took leaves and flowers

of ornamental plants, such as persimmons *Diospyros* spp., cranesbills *Geranium* spp. and storksbills *Pelargonium* spp. (A. Ring, pers. comm. 1990).

Food scraps discarded on the lawns attracted bowerbirds, as well as bread being fed to ducks. On one property near Mount Keira, bowerbirds took dog biscuits from the verandah (A. Ring, pers. comm), often carrying them to a nearby perch. Some were presumably eaten; however most were either dropped or used as bower decorations.

Commensalism with other species

Satin Bowerbirds were recorded foraging in mixed-species flocks on 30 occasions throughout the year (Table 2). These foraging associations included more than half of the fruit species in the diet (15 species), and involved seven species of birds. Commensalism with the Pied Currawong *Strepera graculina* was recorded on 11 separate observations, in six of which currawongs swooped or chased bowerbirds away. No antagonism was recorded in foraging associations between bowerbirds and the other six species.

DISCUSSION

This study confirms that Satin Bowerbirds exploit at least 26 of the 83 species of fleshy fruit-producing plants in the Illawarra rainforests. Although a number of detailed studies of the Satin Bowerbird have included dietary analysis (Donaghey 1981; Church 1997; Gosper 1999; Rose 1999; S. Hardy and T.E.

Table 2

Fruiting species that were the subject of commensalism between Satin Bowerbirds and other avian frugivores.

| Fruiting species | Bird species involved (month/s) |
|----------------------|---|
| Illawarra Flame Tree | Pied Currawong (Aug) |
| Staff Vine | Green Catbird (Apr), Silveryeye (Apr) |
| Kangaroo Vine | Pied Currawong (Mar) |
| Water Vine | Pied Currawong (Jun) |
| Churnwood | Pied Currawong (Feb), Topknot Pigeon (Feb) |
| Jackwood | Pied Currawong (May), Topknot Pigeon (May) |
| Native Tamarind | Pied Currawong (Jan), Lewin's Honeyeater (Jan), Topknot Pigeon (Jan) |
| White Quandong | Green Catbird (Jan), Topknot Pigeon (Jan) |
| Sandpaper Fig | Green Catbird (Mar), Pied Currawong (Mar), Lewin's Honeyeater (Mar) |
| Moreton Bay Fig | Pied Currawong (Jan), Channel-billed Cuckoo (Oct), Topknot Pigeon (Jan, Mar, Oct) |
| Small-leaved Fig | Pied Currawong (Oct), Lewin's Honeyeater (Oct), Topknot Pigeon (Oct) |
| Bolly Gum | Pied Currawong (Mar), White-headed Pigeon (Mar) |
| Brown Beech | Topknot Pigeon (Dec) |
| Crabapple | Green Catbird (Mar), Pied Currawong (Mar) |
| Tree Heath | Green Catbird (Oct), Lewin's Honeyeater (Oct) |

Robson in Frith and Frith 2004), the present study is important in its geographical coverage toward the southern part of the species' distribution. The Illawarra rainforests are one of six major rainforest regions in NSW, though likely to have a less diverse assemblage of fruiting plants available than its northern counterparts (Floyd 1982; Keith 2004).

Correlations between fruiting phenologies and breeding seasonality in frugivorous birds have been shown for tropical and subtropical rainforests (Snow and Snow 1964; Crome 1975, 1976; Donaghey 1981; Innis and McEvoy 1992). This trend does not appear to continue into temperate climates for the Satin Bowerbird. In the present study, phenological data showed that the Illawarra rainforests had the least number of reliable fruiting species during the breeding season from September to December. During this period, bowerbirds were observed feeding on seven species. CCP for Brown Beech occurred within the breeding season, while two species, Wild Quince and Kangaroo Vine *Cissus antarctica*, were at the end of their CCP. A further species, Moreton Bay Fig was consumed in the lead up to its CCP. The remaining three species exploited during the breeding season, White Quandong, Small-leaved Fig *Ficus obliqua* and Tree Heath *Trochocarpa laurina*, produced crop sporadically.

The few observations of invertebrate predation occurred in spring and early summer, suggesting an accentuated reliance on these food sources during the breeding season. Other authors have suggested that the timing of nesting in the Satin Bowerbird coincides with peak invertebrate abundance (Vellenga 1980;

Donaghey 1981). Marshall (1950a,b, 1954) highlighted the availability of high-protein prey such as Bogong Moths, termites, beetles and cicadas in the nesting season, and exploitation of these by female bowerbirds attending to chicks. Sufficient protein in the nestling diet has apparently facilitated female-exclusive brood care without reducing breeding efficiency (Donaghey 1981). In addition, an abundance of insects during the nesting season provide a staple prey source for male bowerbirds attending their bowers, allowing them to become sedentary; thus reducing the incidence of bower destruction and ornament theft by conspecifics and optimising male-female contact (Donaghey 1981).

The consumption of herbs was mainly focused on the month of September, the beginning of the breeding season. Grazing on manicured lawns has previously been observed (Goddard 1999). In addition, flocks of bowerbirds forage for herbs in winter to early spring, which apparently replace fruits as the staple food source in September (Donaghey 1981; Higgins *et al.* 2006). In the present study, reliable fruiting plants in the diet during this period were limited to Wild Quince and Kangaroo Vine.

Bowerbirds fed on a number of species that did not fruit on a reliable basis (i.e. did not have a CCP). These species represented approximately one-third of the fruit component of the diet. With the exception of Native Tamarind *Diploglottis australis*, White Quandong and Small-leaved Fig, most of these species were only recorded being fed upon on one or two occasions, consequently no evaluation could be made of their significance in the diet. It would appear that bowerbirds are opportunistic foragers, especially given their dietary adaptability towards non-natural foods. Other authors have also recorded bowerbirds taking bread (Crowe 1978; Passmore 1982; Holland 1999), as well as broccoli leaves (Holland 2000), cakes (Marshall 1932), cheese (Crowe 1978), honey-syrup (Vellenga 1980), chicken feed and commercial seed mix (Higgins *et al.* 2006).

There appears to be a large dietary overlap between the Satin Bowerbird and other frugivorous birds in the Illawarra rainforests (cf. Waterhouse 1995, 2001). Mixed-species foraging associations occurred around more than half of the fruit species in the diet. Of the seven species observed feeding with bowerbirds, only the Pied Currawongs was recorded to respond antagonistically toward bowerbirds.

CONCLUSION

Frugivores play a keystone role in subtropical rainforests as seed dispersers for up to 80 percent of rainforest flora (Webb and Tracey 1981; Green 1993). The Illawarra rainforests have been subject to extensive vegetation clearing, causing habitat fragmentation and isolation of some fauna populations (Stork *et al.* 2008; Riviere and Rowlatt 2013). Robinson (1977) introduced the concept of restoring corridors between these habitat remnants to facilitate wildlife movements, improving animal and seed dispersion (Price *et al.* 1999; Cramer *et al.* 2007; Gomes *et al.* 2008). The broad dietary overlap between various avian frugivores may possibly allow uniform approaches to managing these species in the context of habitat connectivity to be successful. Hence, management directions to assist the Satin Bowerbird may be advantageous to other frugivorous species, and vice versa.

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