Meeting an expanding human population's needs whilst conserving a threatened parrot species in an urban environment

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Abstract

The human population of Perth, Western Australia is currently 1.9 million and is predicted to more than double by 2061. The increased housing and infrastructure required to support this population will conflict with the habitat requirements of the Carnaby's cockatoo (*Calyptorhynchus latirostris*), a threatened parrot that inhabits the suburbs of Perth outside its breeding season. To understand how this species uses the landscape and identify possible ways to mitigate the impact of future development, we undertook flock follows, assisted by satellite telemetry of 23 birds. The cockatoos have adapted to urban living by using non-native trees for communal night roosting, using artificial water sources, and by relying heavily on exotic food sources. By developing a better understanding of how these cockatoos have adapted to urban habitats we can use a suite of innovative conservation strategies to complement traditional habitat conservation measures. These strategies include urban and landscape planning decisions that consider the specific needs of cockatoos and that involve the community in the conservation of a threatened species.

Keywords: adaptation, urban ecology, Carnaby's cockatoo, parrot.

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1 Introduction

The Australian Bureau of Statistics [1] predicts that the human population of Perth, Western Australia will grow from 1.9 million to between 4.4 and 6.6 million by 2061, creating the need to greatly increase housing and infrastructure on the Swan coastal plain. A species at the centre of many development debates is Carnaby's cockatoo (*Calyptorhynchus latirostris*). Carnaby's cockatoo is a threatened parrot endemic to the south west of Western Australia that inhabits the suburbs of Perth during its non-breeding season [2–4]. Its distribution means that its feeding, breeding or roosting habitat is often identified as being at risk from development.

Habitat loss has been the main threatening processing leading to Carnaby's cockatoo being listed as a threatened species. Large-scale clearing of inland semi-arid sandplains occurred in the post-WWII period for extensive cereal cropping and caused cockatoo populations to decline in much of their breeding habitat [5]. Cockatoos migrate from inland areas to more coastal areas during the non-breeding season where they formerly fed upon large expanses of *Banksia* woodland and proteaceous heath. An estimated 70% of this *Banksia* woodland has been lost with over 90% lost within a 20km radius of central Perth [6]. The remaining *Banksia* woodland has been nominated as a Threatened Ecological Community under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* [6].

The type, extent and density of development on the Swan coastal plain continues to evolve. Urban development that began along the Swan River in 1829 now extends linearly along the coast for more than 120km to the north and south [7]. This sprawl has been caused by the preference of Perth residents to live in fully detached houses on their own block of land [8]. This evolved from early requirements to have a minimum block size of a quarter acre ($1012m^2$) to ensure adequate separation of water extraction for drinking and to leach drains for sewerage disposal [7]. In 1955 average housing blocks were the largest in Perth's history being $750–1008m^2$ compared to developments today where 'cottage lots' of $380m^2$ or $260m^2$ are common [9]. As lot sizes have reduced there has been a corresponding increase in footprint size of houses and a reduction in the size of home gardens [9]. Urban infill is replacing gardens of larger blocks with more houses resulting in loss of urban forest [10]. The resulting landscape is very different to the natural habitat that existed before European settlement and through urban infill and consolidation will continue to change.

Parrot species in general have fared better than other groups of birds in urban environments because of the plasticity of their behaviour and ability to adapt to novel food sources and landscapes [11, 12]. In Australia, urban food resources have contributed to the increase in abundance of rainbow (*Trichoglossus haemotodas*) and musk (*Glossopsitta concinna*) lorikeets in Melbourne [13]. Grey-headed flying foxes (*Pteropus poliocephalus*) and black flying foxes (*Pteropus alecto*) have also learnt to use urban environments and increased their range and abundance in two major Australian cities: Melbourne and Brisbane [14–17].

There is evidence that Carnaby's cockatoos have adapted to novel landscapes and food sources. Pine (*Pinus* spp.) plantations were first established on the Swan coastal plain in 1926 and the cockatoos soon began to feed on the new food resource [18], partially offsetting the loss of their natural food resource in *Banksia* woodlands. The cockatoos now remove almost the entire annual crop of pine cones each year and plans to harvest the largest remaining plantations by 2031, to free underground water resources, are expected to have a significant impact on the cockatoos [19].

Carnaby's cockatoo also use liquid amber (*Liquidambar styraciflua*) seed, a popular garden and street tree, as a food source. An example of the adaptable nature of this behaviour comes from February 2000 when a few Carnaby's cockatoo were repeatedly observed experimentally feeding on the seeds of liquid amber trees in a car park. The following year they were observed feeding en-masse devouring the entire crop within a week [20]. This demonstrates their ability to learn to exploit a new food source, and to recruit others to use the food resource.

The urban landscape is effectively a novel ecosystem [21]. We know little about the long term sustainability of novel ecosystems such as this, and it is likely that they will evolve rapidly through processes such as urban infill, urban planning and landscaping trends. If we can identify those elements in the landscape that assist the survival of Carnaby's cockatoo then we can protect and enhance those elements whilst allowing development to occur in other areas. By understanding how Carnaby's cockatoo has adapted we have the ability to plan ahead to ensure that the needs of the cockatoos are integrated into land use planning decisions, landscaping and (re)vegetation plans.

Here we demonstrate the different ways in which Carnaby's cockatoo has adapted to living in urban landscape and how this can be incorporated into an urban conservation strategy for the species. The community, land managers and planners can all be involved in developing and implementing conservation actions.

2 Materials and methods

2.1 Study area

Perth is the capital city of the large state of Western Australia (over 2.5million square kilometres) and is centred on the Swan River. The boundary of the Metropolitan Region Scheme was used to define the extent of this study (Figure 1). It extends from Two Rocks in the north to Singleton in the south and inland to The Lakes. The Darling Scarp bisects the area into the Swan coastal plain, where the majority of urban development has occurred, and the Darling plateau.

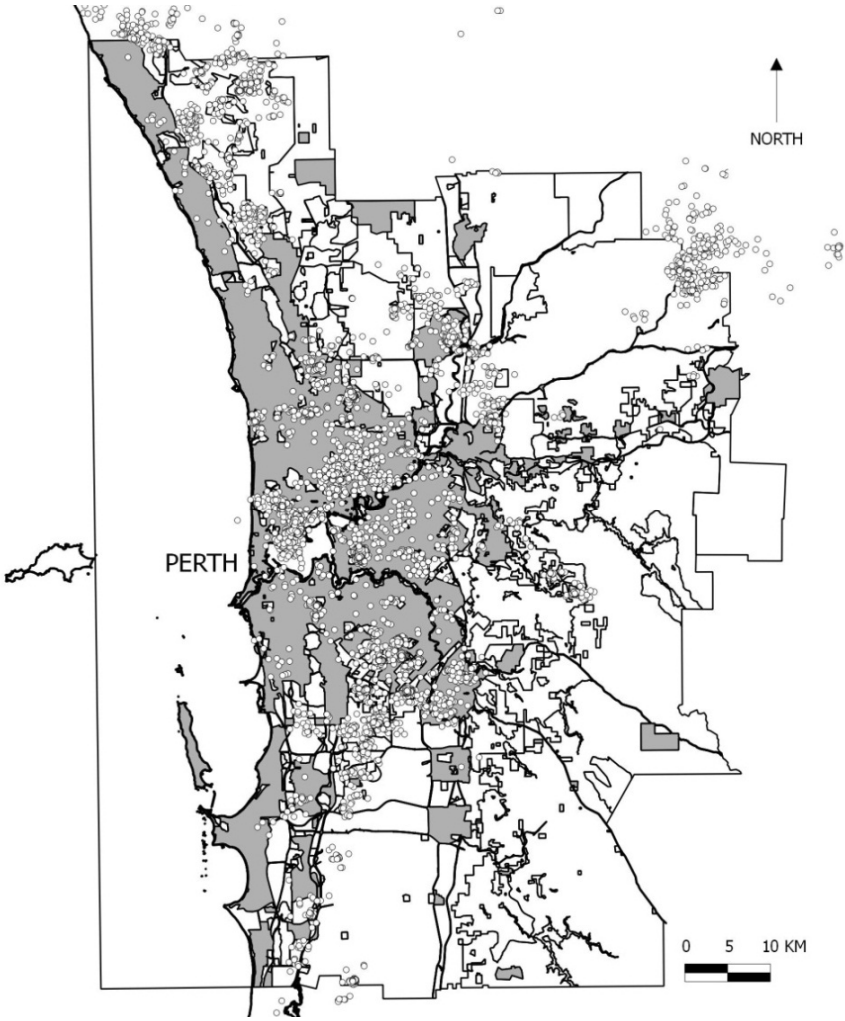

Figure 1: Study area showing satellite telemetry location fixes (circles) for study birds within the Metropolitan Region Scheme (outer black line boundary) and in relation to urban areas (shaded grey).

2.2 Feeding and drinking observations

A total of 23 Carnaby's cockatoos were fitted with satellite tracking devices (Telonics TAV-2617) attached to the underside of the central tail feathers [22]. Flocks containing study birds were followed by vehicle with the aid of an Argos Locator AL-1 (Communication Specialists). If more than one study bird was in a flock, it was counted as one flock follow if the start and end point of the follow was the same for both birds. By following study birds it was possible to estimate

flock size, identify where they roosted at night, how far they travelled from those roosts to forage, what they fed on and where they drank.

A literature review of plant species recorded in the diet of Carnaby's cockatoo was conducted to identify the range of native and exotic foods eaten by the cockatoos. Observations of feeding were recorded during flock follows to identify plants and food items consumed (nectar, seed, grubs, etc.) in the urban landscape and to assess the periods of use by the cockatoos. Observations of drinking were also recorded with the source of water and whether it was permanent or temporary.

2.3 Roost observations

Roosts were identified by two methods: 1) by analysing night time location fixes obtained from satellite tracking devices, and 2) by following study birds directly to roosts. Additional roosts were identified from the Great Cocky Count project which involved an annual census of cockatoos as they arrived at roosts, conducted largely by trained volunteers [23]. Roost locations where a count of >100 birds had been observed through this study or, during the Great Cocky Count (2010–2013) were selected for assessing the type and approximate age of trees used. Aerial photographs of roost locations viewed from Landgate's Map Viewer (https://www.landgate.wa.gov.au/bmvf/app/mapviewer/#) were compared over time to determine if the roost consisted of naturally occurring trees or, if planted, when those trees were planted.

2.4 Records of sick and injured cockatoos

The urban environment can be hazardous to cockatoos due to their large size (520–790g) [3] and their consequent slow time to respond to vehicles when feeding or drinking close to roads. The Perth Zoo, Veterinary Department maintains records of all sick or injured black cockatoos (*Calyptorhynchus* spp.) admitted for treatment. These records were searched for cases attributed to anthropogenic causes, including collision with vehicles.

3 Results

3.1 Flock follows

A total of 23 study birds were fitted with satellite tracking devices and released between 2012 and 2013. In 2013, 12 study birds were followed intensively for between 1 and 121 days (average 71 days) with releases staggered across the year to allow following of study birds throughout the non-breeding season (February and September). These 12 study birds and the flocks that they were associated with provided the majority of the feeding and drinking observations reported in this study. A total of 164 flock follows were undertaken between 2012 and 2013 ranging in length from 7 minutes to 10 hours 28 minutes. Location fixes for study birds were obtained over a large area of the Perth metropolitan and peri-urban area and showed that roads and sparsely vegetated areas are not barriers to their movements (Figure 1).

3.2 Feeding observations

Results of searching the literature for plants used by Carnaby's cockatoo is summarised in an online tool available at: http://www.dpaw.wa.gov.au/ plants-and-animals/threatened-species-and-communities. Of the 130 plant species identified as food sources for Carnaby's cockatoo, at least 33 are not native to the known range of the cockatoo. Field observations from the current study identified pine (*Pinus* spp.), liquid amber, pecan (*Carya illinoinensis*) macadamia (*Macadamia* sp.) and tipuana (*Tipuana tipu*), as sequentially important food sources for the cockatoos on the Swan coastal plain during the non-breeding season: all are exotic species for this region (Table 1). Cockatoos also fed on four previously unreported food plants: fruit of lilly pilly (*Syzygium smithii*), nectar of red-capped gum (*Eucalyptus erythrocorys*), nectar and seeds of yellow gum (*E. leucoxylon*) and seeds of woody pear (*Xylomelum occidentale*).

Table 1: Phenology of feeding activity for Carnaby's cockatoo in the Perth Metropolitan Region Scheme during the non-breeding season indicating peak (black) and lesser (grey) feeding periods. Numbers indicate number of times a group of birds was observed feeding on a food source. E = Exotic to mainland Australia, N = Native to mainland Australia, L = Local Western Australian species.

Genus	Origin	Mar	Apr	May	Jun	Jul	Aug
Araucaria heterophylla (NorfolkIs.pine)	E		1	1	2		
Liquidambar styraciflua (Liquid amber)	E	32	64	68	19	1	
Carya illinoinensis (Pecan)	E	4	17	19	4	3	3
Tipuana tipu (Tipuana)	E			17	15	11	
Jacaranda mimosifolia (Jacaranda)	E			4	1	3	2
Pinus canariensis (Canary Is. pine)	E				1		
Pinus pinaster (Maritime pine)	E	1	1				
Pinus sp. (Pine)	E	25	9	3	2	2	
Prunus amygdalus (Almond)	E			5			
Raphanus raphanistrum (Wild radish)	E				1	2	
Syzygium smithii (Lilly pilly)	E		1				
Protea sp. (Protea)	E		1	1			
Acacia sp. (Wattle)	N/L		1	13	8	8	
Agonis flexuosa (Peppermint)	L		7	4	19		1
Banksia attenuata (Candlestick banksia)	L	13	11	8	18	35	14
B. ericifolia (Heath-leaved banksia)	N					1	
B. illicifolia (Holly-leaved banksia)	L	6			1	3	1
B. littoralis (Swamp banksia)	L					1	
B. menziesii (Firewood banksia)	L	7	5	15	11	16	3
B. prionotes (Acorn banksia)	L	2		3	1	2	
*B. sessilis (*Parrot bush)	L	1	3	3	1	1	
*B. squarrosa (*Pingle)	L					8	
Banksia sp. *(*Banksia)	N/L	2	3	7	10	1	1
Callistemon sp. *(*Bottlebrush)	N	2		1	2		1
Callitris sp. *(*Callitris)	L		1	2	6		
Corymbia calophylla (Marri)	L	2	3	57	46	36	6

Table 1: Continued.

Genus	Origin	Mar	Apr	May	Jun	Jul	Aug
C. ficifolia (Red-flowering Corymbia)	L	1					
Corymbia sp. (Corymbia)	N/L			3	1		
Eucalyptus sp. (Eucalypt)	N/L			3		2	
E. caesia (Silver princess)	L				1		
E. citriodora (Lemon-scented gum)	N		3	5		1	1
E. erythrocorys (Red-capped gum)	L	1	2				
E. gomphocephalus (Tuart)	L			5			
E. leucoxylon (Yellow gum)	N			1		1	
E. marginata (Jarrah)	L	2	11	2	7	6	
E. robusta (Swamp mahogany)	L		7	6	4		
E. todtiana (Coastal blackbutt)	L			3			
Eucalyptus sp. (Eucalypt)	N/L	2	4		4		
Grevillea (Grevillea)	N/L				1	2	
Hakea sp. (Hakea)	N/L			3			1
Hakea laurina (Pin-cushion hakea)	L			1	2		
H. petiolaris (Sea-urchin hakea)	L				1	1	
H. prostrate (Harsh hakea)	L				1		
H. ruscifolia (Candle hakea)	L					1	
H. undulata (Wavy-leaved hakea)	L		1				
Macadamia sp. (Macadamia)	N	4	8	21	11	8	14
Xylomelum occidentale (Woody pear)	L					1	1

3.3 Drinking observations

Carnaby's cockatoos drink opportunistically from a variety of water sources (Table 2). All water sources observed being used by the cockatoos in urban areas were created or modified by humans. Bird baths and puddles were the most popular water sources (Table 2).

Table 2: Carnaby's cockatoo drinking observations during the non-breeding season in the Metropolitan Region Scheme. Reliability refers to the availability of the water and indicates whether the water source is available permanently for the cockatoos or less often.

Water source	Reliability	Number used
Bird bath	Variable	25
Puddle (bitumen roads, concrete paths etc.)	Temporary	25
Roof gutter	Temporary	11
Stock trough	Reliable	10
Lake	Permanent or seasonally reliable	8
Drain	Temporary	3
Water feature/fountain	Reliable	2
Dam	Seasonally reliable	1
Lawn (dew)	Temporary	1
Cemetery (grave ornaments filled by reticulation)	Temporary but reliable	1
Tree (water on leaves)	Temporary	1
Stream	Seasonally reliable	1

3.4 Roosting observations

Cockatoos readily, and even preferentially, use planted trees for roosting. Roost trees were typically planted more than 20 years ago (Table 3). Of the 31 roosts known to be used by more than 100 cockatoos on the Swan coastal plain, only six consisted either partially, or wholly of naturally occurring trees in remnant vegetation (Table 3). Cockatoos most commonly roosted in planted Eucalypts or pines.

Table 3: Planting period for roost trees of roosts located on the Swan coastal plain recorded to be used by more than 100 birds, based on historical aerial photography.

Roost ID	Location	Trees Planted	Roost Tree Type
MELWINR001	Winthrop	Before 1953	Pines
MELWINR003	Winthrop	Before 1953	Pines
MELMURR001	Murdoch	Before 1953	Pines
COCSCCR001	Success	Between 1953 and 1965	Pines
SWALEXR002	Lexia	Between 1953 and 1965	Pines
WANJANR005	Jandabup	Just before 1965	Pines
SWAMELR001	Melaleuca	Just before 1965	Pines
WANPINR005	Pinjar	Between 1965 and 1974	Pines
ROCBALR001	Baldivis	Between 1965 and 1974	Pines
SEROAKR002	Oakford	Between 1981 and 1985	Pines
SOUCOMR001	Bentley	Before 1953 (pines)	Pines and planted Eucalypts
NEDNEDR001	Nedlands	Various, some pre 1953, most by 1965	Planted Eucalypts
CAMFLOR001	Shenton Park	Between 1953 and 1974	Planted Eucalypts
SEROAKR005	Oakford	Between 1965 and 1979	Planted Eucalypts
SWABALR001/4	Ballajura	Between 1979 and 1981	Planted Eucalypts
WANPINR007	Pinjar	Between 1981 and 1985	Planted Eucalypts
SEROAKR001	Oakford	Between 1981 and 1995	Planted Eucalypts
GINWOOR001	Woodridge	Between 1981 and 1999	Planted Eucalypts
	Banjup	Between 1985 and 1995	Planted Eucalypts
ARMHARR001	Harrisdale	Between 1985 and 1995	Planted Eucalypts
KWIWANR002	Wandi	Between 1985 and 1995	Planted Eucalypts
27 (this study)	Forrestdale	Various but mostly between 1985 and 1995	Planted Eucalypts
40 (this study)	Belhus	Between 1985 and 2000	Planted Eucalypts
WANNARR001	Mariginup	Between 1985 and 2000, most by 1995	Planted Eucalypts
COCBANR001	Banjup	Between 1995 and 2000	Planted Eucalypts
GOSCNVR001	Canning Vale	Between 1953 and 1963	Native with planted Eucalypts
JOOPADR001	Padbury	Between 1974 and 1977	Native with planted Eucalypts
COCHAMR001	Manning	Between 1985 and 1995	Native with planted Eucalypts
STINORR001	North Beach	Mostly between 1965 and 1974	Native with planted Eucalypts
WANYANR006	Yanchep	Some planted before 1965	Native with planted Eucalypts
70 (this study)	Jane Brook		Native

3.5 Records of sick and injured cockatoos

During the five-year period from 2008/09–2012/13 a total of 530 Carnaby's cockatoos were admitted to the Perth Zoo Veterinary Department (Table 4). These birds accounted for 59 percent of black cockatoo admissions, with the remainder comprising two other species endemic to the southwest of WA (*C. baudinii* and *C. banksii naso*).

Table 4: Fate of Carnaby's cockatoos admitted to the Perth Zoo during 2008/09–2012/13. Birds transferred to wildlife carers after initial treatment had the potential to be released back to the wild.

	Euthanised	Dead on arrival or died in care	Transferred to wildlife carer	**Total**
2008/09	31	17	31	**79**
2009/10	37	14	50	**101**
2010/11	38	7	45	**90**
2011/12	64	21	38	**123**
2012/13	64	25	48	**137**
Total	**234**	**84**	**212**	**530**

Based on results of detailed veterinary examinations, radiographs, and post-mortem data for the period 2000–2009, human-related activities such as vehicle strikes, gunshots and tree felling, accounted for 28 percent of the cockatoo admissions (all three species combined). A further 48 percent of admitted birds had suffered trauma of an indeterminate origin. Juvenile birds (< 12 months of age) made up 39 percent of all cockatoo admissions (Perth Zoo unpublished data [24]).

One study bird fitted with satellite tracking device was suspected to have been struck by a vehicle and another was shot and killed near a commercial pome fruit orchard.

4 Discussion

4.1 Ability to adapt to habitat changes

The adaptability of the Carnaby's cockatoo is demonstrated by their ability to utilise novel aspects of the urban landscape to find food, water and roosts, and to feed on novel food sources. The satellite-tracked cockatoos clearly show that they use a very large portion of the built landscape of Perth (Figure 1). Other evidence that black cockatoos, such as Carnaby's, can adapt to modified landscapes come from forested areas where three taxa of black cockatoos endemic to the south west of Western Australia used rehabilitated gold mine sites for feeding within eight years [25]. The birds must move through the rehabilitated area to discover plants of a suitable age to provide the seed, nectar or grubs on which they feed. In both these situations the cockatoos must navigate large expanses of modified landscape to find food, water, roost and nest sites.

Modified landscapes, particularly the parks and gardens of urban areas, contain many plant species that are introduced. The plants are often not considered as important as native species for urban wildlife, especially those plants with weedy tendencies. However, non-native species are not universally undesirable. Shackelford *et al*. [26] discuss the desirability of native vs non-native species and argue it is important to weigh up a species impact and role in a system before determining its desirability, irrespective of its identity or origin. This is very applicable to both Carnaby's cockatoo in Western Australia and yellow-tailed black cockatoos, found in south eastern Australia, which are both dependent on introduced pines for survival [19, 27]. The aleppo pine (*Pinus halepensis*), which is key to the survival of yellow-tailed black cockatoos, is a proclaimed pest plant species under the South Australian *Natural Resources Management Act 2004* [27]. The dependence of Carnaby's cockatoo on a variety of non-native foods in urban areas, including liquid amber, tipuana and nut trees, also demonstrates that these trees have important roles in the landscape in addition to the ornamental properties that make them desirable to human residents.

The trees and shrubs planted in gardens provide a variety of foods that potentially increase the availability of food during periods of natural food scarcity [17]. As climate change alters the frequency and intensity of drought, fire and flood events [28], food resources in natural habitats will become increasingly unpredictable. In comparison, the watered gardens and public open spaces of cities and towns provide a relatively abundant and reliable food source for those species that are able to adapt to urban living [29], as well as a potential buffer against the effects of climate change.

4.2 Developing a conservation strategy

Carnaby's cockatoos are well known to residents of Perth as they form large noisy flocks and their destructive feeding habits leave debris below feed trees. The presence of the cockatoos and the *Banksia* woodland that they naturally inhabit gives Perth its 'sense of place' that helps identify it as home to those that live there. If humans are to create a resilient landscape that maintains this 'sense of place' and supports Carnaby's cockatoo now and into the future, it is important to conserve adequate areas of natural habitat and to make the built environment as useful as possible to the cockatoos.

To conserve species in an urban landscape it is necessary for individuals in the community to have an understanding of issues and to 'buy-in' [30]. Community education and involvement must be a part of any conservation strategy in the urban landscape. The community can assist by planting food plants in their garden, providing water in bird baths, reporting injured cockatoos and participating in community conservation projects. Citizen science projects such as the Great Cocky Count provide an opportunity to educate the public, create greater ownership by the community, and help to conserve the species.

It is necessary for researchers to engage with planners and policymakers to determine how barriers to implementation of wildlife-friendly conservation actions can be removed or how actions can fit within existing 'rules' [30]. Data such as the types generated in this study, have shown the adaptability of the

species, and enables us to implement a broad suite of conservation actions to complement traditional habitat and species conservation measures. Landscape planners can incorporate food plants and roosting trees into their landscaping and can design ornamental lakes with sloping banks to allow cockatoos to drink safely. Roosting habitat can be planted around sporting ovals, public open spaces and schools where shade is also desired.

With so many influences on Carnaby's cockatoo there is a great responsibility for conservation managers to get it right. It is important to appreciate that a novel landscape cannot exactly fulfil the needs of the cockatoos in the same way as the natural landscape once did, and this will affect variables such as nutrition, movement patterns and survival rates of cockatoos.

The diet must meet an individual's daily energy requirements, provide sufficient nutrients to prepare the birds for breeding and, in breeding areas, must also support the raising of chicks. Comparison of the nutrient profiles of indigenous and introduced species consumed by orange-bellied parrots (*Neophema chrysogaster*) indicates that introduced species may not provide adequate nutrition so it may not be appropriate to revegetate sites with introduced species [31]. Glossy black-cockatoos (*C. lathami*) have a highly specialised diet and it has been suggested that although they may be able to meet their immediate energy needs when feeding on non-preferred species of *Allocasuarina*, they may be unable to breed and thereby sustain populations [32]. Until we know more about the nutritional consequences of non-native foods for Carnaby's cockatoos it is important to ensure conservations efforts continue to focus on retaining native vegetation and that any food plants provided in the urban landscape are considered complementary.

It is also important to consider the safety of the cockatoos when providing food, particularly close to busy roads. To minimise the number of cockatoos killed or injured by vehicle strikes it is advisable to avoid planting food plants close to roads or if necessary, to select the most suitable species for the location. For example, cockatoos feed in the canopy of tipuana and liquid amber trees, so these species could be planted in closer proximity to roads in comparison to pines, *Banksias* or nut trees where cockatoos often forage on the ground below and would therefore be at greater risk of being struck by vehicles. Similarly, cockatoos should be discouraged from drinking on roads by repairing potholes or reprogramming or reconfiguring reticulation to ensure puddles do not form on roads. Ensuring optimal drainage from road surfaces into drainage areas is also important, not only in newly constructed roads, but also those that are later modified or repaired. In reality we cannot control which plants, native or exotic, cockatoos choose to feed on, roost in or where they drink. However, we can influence the type and number of opportunities that they have so that they are safer.

Carnaby's cockatoo is a highly adaptable species in the urban landscape. Humans can provide water sources they will use, create roosting habitat and plant cockatoo food. Development of data sets on how urban resources are exploited, located and their importance will allow us to direct conservation efforts more effectively. For Carnaby's cockatoo there are a broader suite of opportunities to assist in its long term conservation than the traditional strategy of conserving as

much natural habitat as possible. There is real potential for win-win situations such that the compromises that are traditionally associated with conflicts between human needs and those of threatened species are avoided. We must make the human altered landscape more resilient to ensure the needs of cockatoos can be met now and into the future. It is a unique scenario that a threatened species can be so readily observed in a capital city and that the community can be so involved in conservation efforts.

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