



Clean Air and
Urban Landscapes
Hub

National Environmental Science Programme

Biodiversity and human wellbeing considerations in managing the urban forest of a global biodiversity hotspot

Clean Air and Urban Landscapes Hub

December 2020

About the Clean Air and Urban Landscapes Hub

The Clean Air and Urban Landscapes (CAUL) Hub is funded by the Australian Government's National Environmental Science Program. The remit of the CAUL Hub is to undertake "Research to support environmental quality in our urban areas". This includes research on air quality, urban greening, liveability and biodiversity, with a focus on practical implementation of research findings, public engagement and participation by Indigenous Australians. The CAUL Hub is a consortium of four universities: The University of Melbourne, RMIT University, the University of Western Australia and the University of Wollongong.

www.nespurban.edu.au

Acknowledgements

We acknowledge the Traditional Owners of the lands and waters where this research took place, The Whadjuk people of the Noongar nation, and pay our respects to Elders past, present and future. We acknowledge that all cities in Australia were built on Indigenous land, and that this land was never ceded.

Please cite this document as

Dickinson D. and Ramalho C.E. (2020) Biodiversity and human wellbeing considerations in managing the urban forest of a global biodiversity hotspot. Report prepared by the Clean Air and Urban Landscapes Hub.

The Clean Air and Urban Landscapes Hub and Threatened Species Recovery Hub are funded by the Australian Government's National Environmental Science Program

Contents

Introduction.....	3
Research questions	5
Methods	6
The study area	6
Selection of LGAs.....	6
Interviews	7
Data analysis.....	8
Results and discussion.....	9
Importance of the urban forest	9
Functions of the urban forest	10
Spatial segregation of urban forest functions	13
Factors influencing urban forest composition.....	15
Final remarks	23
References.....	24

Figures

Figure 1. Forest Red-tailed black cockatoos feeding on a Cape Lilac, a non-native tree species that is abundant in the streetscapes of Perth (Photo: Erika Roper).	3
Figure 2. The natural vegetation of the Perth Area has some of the highest rates of insect pollination in the world. Both native and non-native bees are attracted by various urban trees species (Photo: Cristina E. Ramalho).	4
Figure 3. Although not endemic to Western Australia, broadleaf species such as this Moreton Bay Fig can provide shade/cooling and biodiversity benefits (Photo: Liz Grandmaison).	5
Figure 4. Map of the study area.....	7
Figure 5. Importance of the urban forest as identified by LGA practitioners from different areas of expertise (axis shows the proportion (%) of practitioners that mentioned a particular theme relative to practitioners from the same area of expertise).	10
Figure 6. A comparison of the consideration given to four particular urban forest functions by LGA practitioners (the y-axis represents an average score, the closer it is to +1, the more that function features in management decisions).....	11
Figure 7. “Sense of Place” had different meanings for different practitioners (x-axis shows % responses)	12
Figure 8. Summary of themes raised by LGA practitioners who spoke about urban forest as food/habitat for significant fauna (x-axis shows proportion of responses).....	13
Figure 9. Urban forest priorities/considerations for different spatial locations, which suggests that the planning of urban forest functions is spatially segregated (axis shows proportion of responses).	14
Figure 10. Main constraints in streetscapes mentioned by practitioners (shown as proportion of responses).	14
Figure 11. Factors influencing urban forest outcomes. This framework is adapted from Vogt 2020, with the sub-items within each main factor being the themes identified during the interviews with LGA practitioners.....	15

Tables

Table 1. Key attributes of the LGA practitioners interviewed in the scope of the study. In four LGAs (two outer metro and two inner metro), practitioners from all three areas of expertise were interviewed.	9
Table 2. Examples of quotes for each of the factors/themes and sub-themes identified during the interviews (organised based on the social-ecological model by Vogt 2020).	22

Introduction

Urban forests – defined as all the trees, forests, and associated vegetation growing in cities and towns (Vogt, 2020) – play a crucial role in the delivery of multiple benefits for people and their environment, from human health and wellbeing, to cooling and microclimatic amelioration, pollution filtration and improvement of air quality, and stormwater management (Livesley et al., 2016, Nowak et al., 2014). The importance of urban trees in shading and cooling streetscapes and public open spaces is becoming ever more important in the context of climate change and the need to mitigate urban heat island effects (Rahman et al., 2020). Many cities in Australia and worldwide have developed urban forest management plans, and urban tree management is an important component of municipal responsibilities (Ordóñez et al., 2019).



Figure 1. Forest Red-tailed black cockatoos feeding on a Cape Lilac, a non-native tree species that is abundant in the streetscapes of Perth (Photo: Erika Roper).

Urban forests are also important for biodiversity conservation (Wood and Esaian, 2020, Alvey, 2006). This is because urban forests can provide crucial habitat resources and connectivity, especially to birds and insects that are native to adjacent natural ecosystems, but also those that are migratory (Wood and Esaian, 2020, Alvey, 2006). Urban forests can also provide novel resources, i.e., resources that species 'have learnt to explore', and that are not part of their traditional, native “portfolio” of resources (Valentine et al., 2020). For example, in Perth, Australia, the threatened forest red-tailed black cockatoos (*Calyptorhynchus banksii naso*) have in recent decades begun foraging on the non-native cape lilac trees (*Melia azedarach*), which are frequently planted along residential streets and in gardens. In Sao Francisco, US, the

caterpillar of the Western Tiger Swallowtail butterfly (*Papilio rutulus*) uses London Plane trees as a food resource, and the non-native Canary Island Date Palms (*Phoenix canariensis*) has contributed to the range extension of the Hooded Orioles (*Icterus cucullatus*) (Sao Francisco Public Works, 2014).



Figure 2. The natural vegetation of the Perth Area has some of the highest rates of insect pollination in the world. Both native and non-native bees are attracted by various urban trees species (Photo: Cristina E. Ramalho).

The Perth Metropolitan Area is located in the South West Australian Floristic Region, a global biodiversity hotspot with very high plant species diversity and endemism rate that is also under significant threat (Hopper and Gioia, 2004, Myers et al., 2000). Two iconic, threatened cockatoo species, the forest red-tailed black cockatoo and the Carnaby's cockatoo (*Zanda [Calyptorhynchus] latirostris*) use native and non-native street trees as habitat foraging and roosting resources (Williams et al., 2017, Stock et al., 2013, Johnstone et al., 2017). Furthermore, the predominant remnant plant community type, *Banksia* woodlands, is a threatened ecological community with a high diversity of plants, birds, insects, and reptiles (Threatened Species Scientific Committee, 2016).

In this study, we aimed to understand how biodiversity and human wellbeing considerations are being taken into account in urban forest planning and management in the Perth Metropolitan Area. We interviewed practitioners from ten Local Government Authorities (LGAs), including practitioners tasked with implementing urban forest strategies but also those with carriage of local biodiversity plans and local health and wellbeing plans. We sought to explore the factors underpinning current species selection, potential synergies and conflicts in urban forest planning perceived by practitioners, and the services and disservices of urban

forest to biodiversity and human wellbeing. Approximately half of the 32 LGAs that form the Perth and Peel Metropolitan Region have developed urban forest strategies within the last 5 years, and there is no cohesive metropolitan approach to urban forest. We hope that by understanding how different LGAs are attempting to optimize the delivery of urban forest benefits, and the challenges they face in doing so, that we can help inform the way forward, towards a more sustainable, biodiverse and climate resilient future.



Figure 3. Although not endemic to Western Australia, broadleaf species such as this Moreton Bay Fig can provide shade/cooling and biodiversity benefits (Photo: Liz Grandmaison).

Research questions

This study presents an opportunity to explore the perceptions of LGA practitioners about their urban forest, including those involved in urban forest planning and management, but also those involved in urban biodiversity conservation, and public health and wellbeing. This study addresses the following research questions:

- What biodiversity, human wellbeing, and/or other considerations influence the planning and management of urban forest in the Perth Metropolitan Area?
- What are the synergies and conflicts perceived by practitioners familiar with urban forestry, biodiversity conservation and public health?
- How can a more rounded approach to biodiversity and human wellbeing be accommodated by species selection for urban forest in a global biodiversity hotspot?

Methods

The study area

The Perth Metropolitan Area is home to approximately 2 million people (Australian Bureau of Statistics, 2020), and its sprawling urban footprint stretches nearly 150 km, from north to south. Population growth and urbanisation are contributing to infill development, densification and loss of urban forest, as evidenced by a 2.3% loss of canopy cover in Perth between 2009 and 2016, largely as a consequence of land development (DPLH *et al.* 2018). These pressures are set to continue, with the metropolitan population forecast to grow to approximately 2.5 million by 2031 (DPLH, 2020) and Western Australian state government policy actively promoting higher density development and greater infill (DPLH and WAPC 2018).

As previously mentioned, approximately half of the 32 Perth metropolitan LGAs have developed urban forest strategies within the last 5 years, with a view to combating the loss of urban forest. Nearly all plans cite an objective to increase canopy cover in order to mitigate the Urban Heat Island effect. Other cited objectives for urban forest include: aesthetics/visual appeal, sense of place and character of an area, encouraging physical activity, and mental health/wellbeing. Ecological factors that are mentioned the most in urban forest strategies are: habitat and food for fauna (birds, animals and insects), ecological linkage (movement corridors for fauna), and species diversity, largely in the context of maximising tree species diversity to increase pathogen resilience. Significant fauna mentioned in LGA biodiversity plans include: chuditch, numbat, western ring-tailed possum, cockatoos (Carnaby's Cockatoos and Forest Red-Tailed Black Cockatoos), phascogale, long-necked turtles, peregrine falcon, and native bees.

Selection of LGAs

Ten LGAs were selected for the study based on the following criteria:

- Sample must secure a good geographical spread of the Perth metropolitan region and incorporate both inner and outer ring LGAs (as these are likely subjected to different types of development pressures and therefore different challenges to their urban forests);
- LGAs with Urban Forest Strategies (or equivalent) *and*
- LGAs with Local Biodiversity Strategies and/or explicitly stated biodiversity objectives in their urban forest strategy *and*
- LGAs with Public Health Plans and/or explicitly stated health/wellbeing objectives in their urban forest strategy.

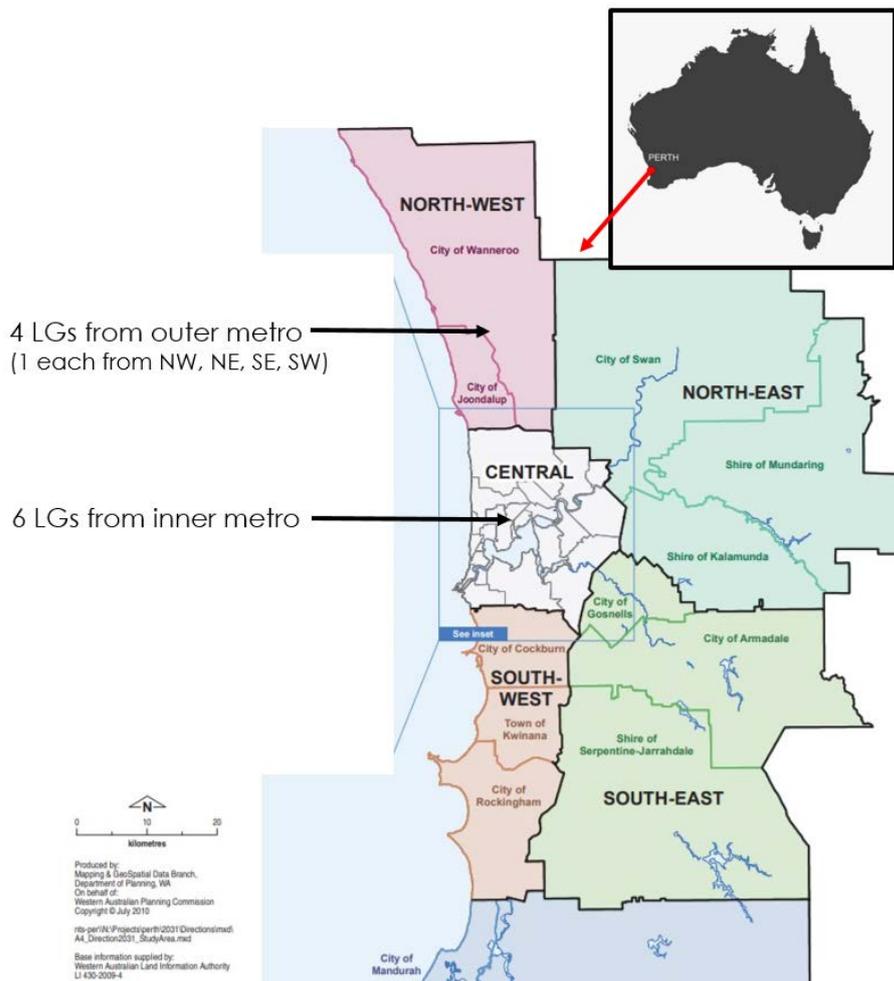


Figure 4. Map of the study area.

Interviews

We used a social-ecological approach to understand the factors that influence the planning and management of urban forest in the Perth Metropolitan Area. To this end, we conducted semi-structured interviews with practitioners from the 10 selected LGAs. From each LGA, we sought interviews with practitioners from each of the following groups:

- Those tasked with designing and implementing the urban forest strategy,
- Those with responsibility for local biodiversity plans, and
- Those responsible for local health and wellbeing plans.

We recruited interviewees using a combination of purposive and snowball sampling. The shortlisted LGAs were contacted to request names of relevant practitioners, or where urban forest practitioners in the target LGAs were known, were contacted directly and asked to nominate colleagues from the other targeted areas of expertise. We contacted practitioners individually and invited them to participate in the research. Where appropriate officers could not be suggested by others, we asked the relevant divisions (e.g. Parks, Environment/Sustainability, Health/Communities) within the LGA to request the name of an appropriate practitioner to send an invitation to. Due to COVID-19 and social distancing requirements, we

offered participants the choice of a face-to-face interview (where permitted) or via online video conferencing.

Interview questions for all practitioners were grouped into five main sections:

- Factors guiding tree species selection – objectives, whether there is a list of preferred tree species, whether it is reviewed periodically and using what criteria, whether there are any rules of thumb or guidelines used to guide what trees get planted where
- Experiences, opinions, perspectives on using different species for different functions
- Ecosystem disservices from the urban forest in the LGA, whether residents complain about particular species and for what reasons, whether the LGA has strategies to remediate/prevent disservices, and whether the LGA monitors services/disservices
- Synergies and challenges
- The way forward

Data analysis

We audio recorded all interviews before transcribing them and importing into NVivo 12 (QSR International) for qualitative analysis. We coded interview data using an inductive approach. Repetitive themes formed the basis of a coding structure that was gradually refined through comparison of new and already-analysed data. We de-identified practitioners for the purpose of analysis and reporting but each was allocated an alpha-numeric tag based on their expertise and location of the LGA. Where quotes have been used as evidence (as per below), attributions are as follows: “UF/Bio/Health practitioner” refers to expertise of the practitioner i.e. Urban Forest, Biodiversity Conservation, or Public Health respectively. Alpha-numeric postscript indicates whether the practitioner is from one of the four Outer Metropolitan (OM) local governments or one of the six Inner Metropolitan (IM) local governments sampled.

Following the coding of data, further analysis was conducted by comparing and contrasting the responses of different groups of practitioners based on the three types of expertise examined and also in relation to particular emergent themes. For the most part, this involved comparing relative proportions of responses.

One particular focus of the analysis was on the perspectives sought from practitioners on four functions of urban forest based on the benefits these functions are known to deliver:

- Shade and cooling in streets and parks (health/wellbeing benefits)
- Sense of place and connection with nature (health/wellbeing benefits)
- Habitat/food for significant fauna (biodiversity benefits)
- Attracting pollinators (biodiversity benefits)

Here, we coded interview responses as +1 when a function was actively considered in urban forest management and -1 when a function was revealed to be a secondary consideration or not considered at all. By averaging values for each function, it was possible to compare the relative importance given to each function on the basis that the closer the average score was to +1, the more consideration was being given to that function in urban forest management decisions.

Results and discussion

Data were collected from 27 interviews with 29 practitioners across the 10 targeted LGAs (Table 1). This represented 25 hours of recorded audio with an average interview length of 55 minutes. Sixteen (16) interviews were conducted online and 11 in person.

Key attributes	Classes	Number of participants
Gender	Male	15
	Female	14
Location	Outer metro LGA	11
	Inner metro LGA	18
Expertise*	Urban forest practitioner	16 (2 had a job role that covered both urban forest and biodiversity)
	Biodiversity practitioner	7
	Health/Community practitioner	6
Level	Managers/officers	21
	Operational/technical staff (arborists/parks)	6
	Operational/technical staff (landscape architects)	2

Table 1. Key attributes of the LGA practitioners interviewed in the scope of the study. In four LGAs (two outer metro and two inner metro), practitioners from all three areas of expertise were interviewed.

Importance of the urban forest

All interviewees were asked why they thought urban forest was important to their LGA. The provision of shade and cooling was highlighted by all practitioners, particularly urban forest and biodiversity conservation practitioners. Biodiversity conservation was the next most important consideration for these two groups of practitioners. Health and wellbeing was mentioned more by health practitioners as was the importance of urban forest to sense of place/character and amenity/liveability (Figure 5).

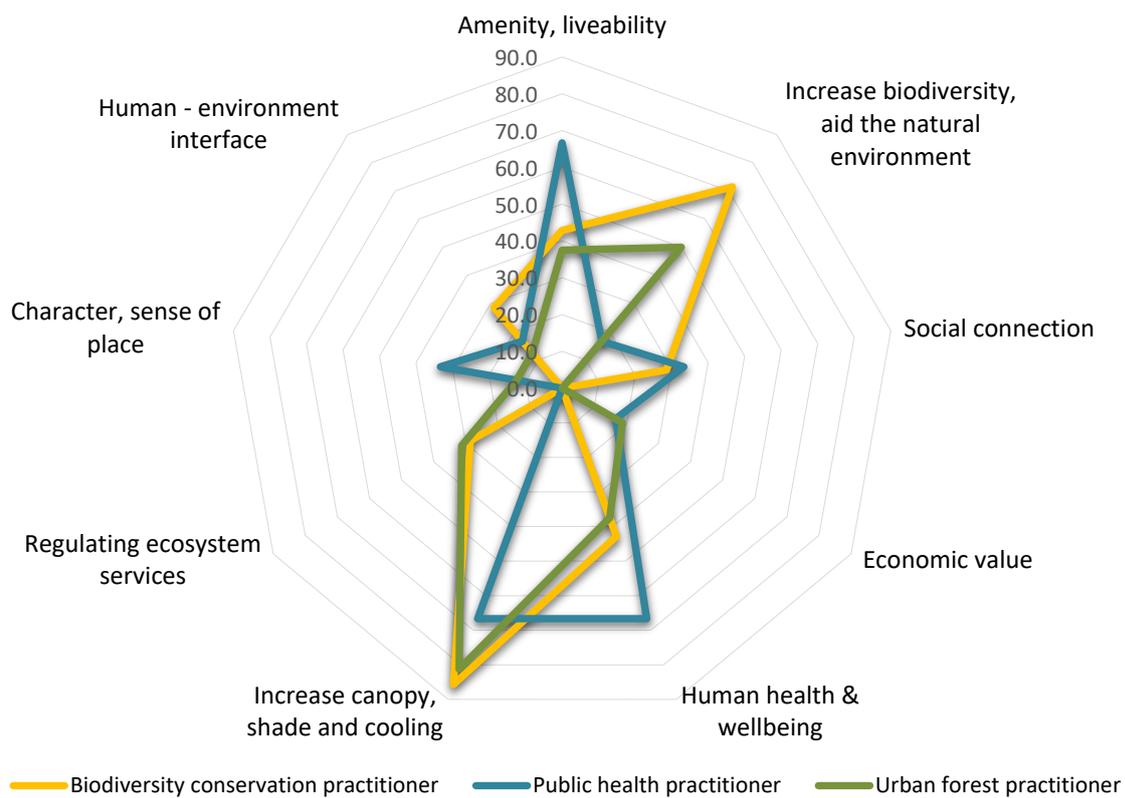


Figure 5. Importance of the urban forest as identified by LGA practitioners from different areas of expertise (axis shows the proportion (%) of practitioners that mentioned a particular theme relative to practitioners from the same area of expertise).

Functions of the urban forest

Interviewees were asked to mention experiences, opinions, perspectives on using particular species for four different functions of the urban forest:

- Shade and cooling in streets and parks
- Sense of place and connection with nature
- Habitat/food for significant fauna
- Attracting pollinators

Shade and cooling and, to a much lesser extent sense of place, were functions actively considered in tree species selection. Biodiversity-related functions, including food/habitat for significant fauna and for pollinators, tended to be a secondary consideration or a by-product of selecting species for some other reason (Figure 6).

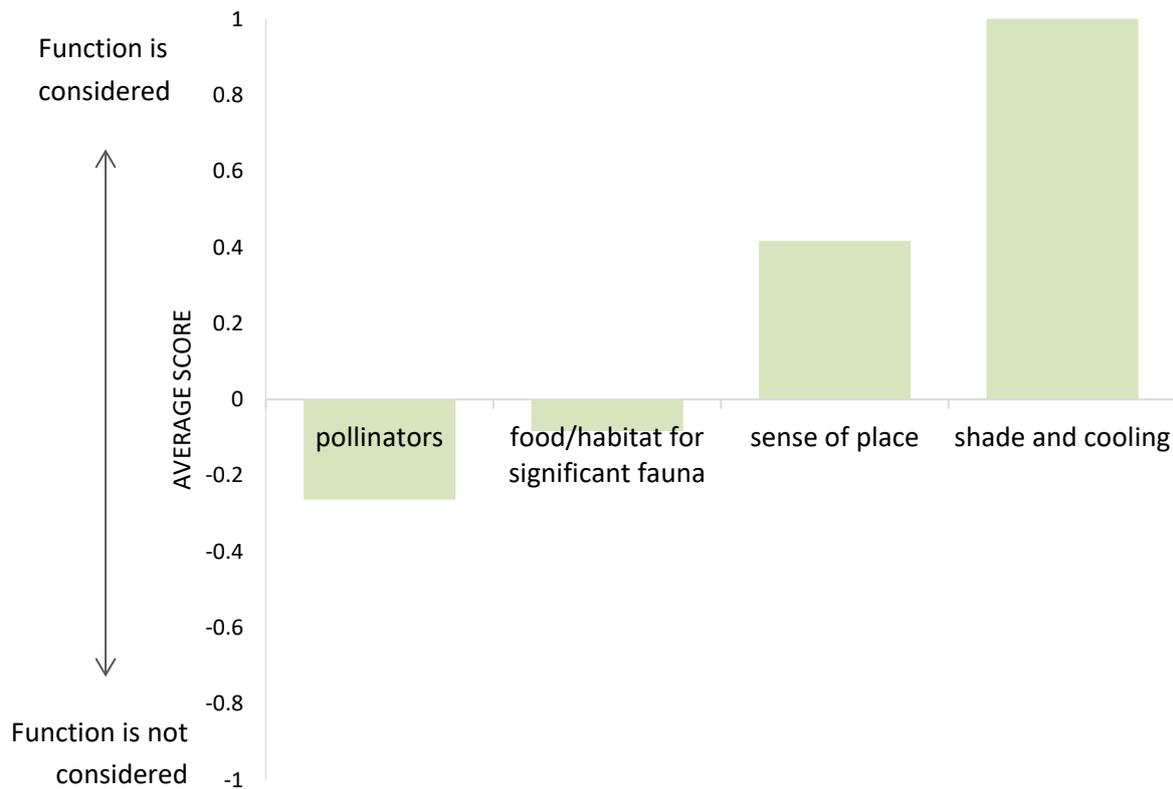


Figure 6. A comparison of the consideration given to four particular urban forest functions by LGA practitioners (the y-axis represents an average score, the closer it is to +1, the more that function features in management decisions)

Shade and cooling

Twenty-three (23) interviewees spoke about shade and cooling. Of these, nearly 70% indicated that maximising canopy/shade was a major consideration – either in terms of planting the “biggest tree that’ll fit in the space” (UF practitioner, OM2) or emphasising it as a priority: “Shade and cooling is our main message that we use for the urban forest plan so that’s the key focus” (UF practitioner, IM3). A quarter of the interviewees indicated that deciduous trees were used for street planting because they provide shade in summer and winter sunshine. While London Plane trees and Moreton Bay Figs were mentioned by a number of interviewees as being species good for shade, a third of interviewees also highlighted the trade-offs that needed to be considered in species selection. This included leaf-drop associated with deciduous trees, fruit-drop and space restrictions (e.g., figs), potential allergies (e.g., London Plane trees), and drought-tolerance: “if canopy cover is the output or the outcome you’re looking for, and shade cast, sparse foliage trees don’t really present that to the same degree. So you’ve got that balance of do you want the shady trees but you want drought tolerant trees that generally don’t have the same aspects of what they deliver” (UF practitioner, IM3).

Sense of place

The interviews revealed differing interpretations of the term “sense of place”. Views centred around two main themes: (1) practitioners who considered “sense of place” to mean avenue planting with single species such as jacaranda and/or iconic trees that could help orient individuals “I live on a street with those trees and I can find those trees when I’m driving around” (UF practitioner, IM3); and (2) practitioners who thought the native Western Australia flora helped define Perth “it’s the only place you can really see those species and it helps you... it makes it feel like home you know? So we do try and... that’s another advantage, other than the ecological side, of local species is this - what is really an emotional attachment to our plants from around here and our home” (UF practitioner, IM1).

By breaking down practitioner understandings of “sense of place” according to their area of expertise, it was perhaps unsurprising that biodiversity practitioners tended to associate sense of place with the native WA flora more so than urban forest practitioners.

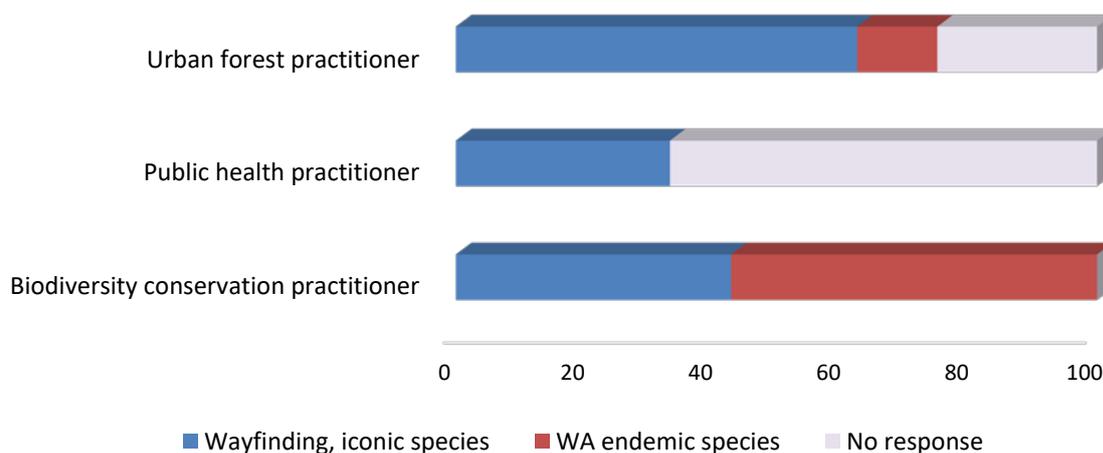


Figure 7. “Sense of Place” had different meanings for different practitioners (x-axis shows % responses)

Resources for significant fauna

During the interviews a number of common themes emerged when discussing the use of urban forest as habitat resources for significant fauna. Almost universally, “significant fauna” was interpreted as meaning black cockatoos (Carnaby’s and/or Forest Red-Tailed Black Cockatoos). Of the 23 practitioners who spoke about urban forest as habitat resources for significant fauna, the majority believed that food/habitat provision for black cockatoos was important, and provided examples of native and/or non-native species planted for this purpose. This may seem to contradict Figure 6 (above) where biodiversity-related functions appeared to be secondary/not-considered, but practitioners’ comments need to be understood in the context of a frequently mentioned disclaimer. Specifically, habitat provision was considered a suitable function for some areas only such as parks/reserves but less so in residential areas/street scapes. Spatial factors are explored further below.

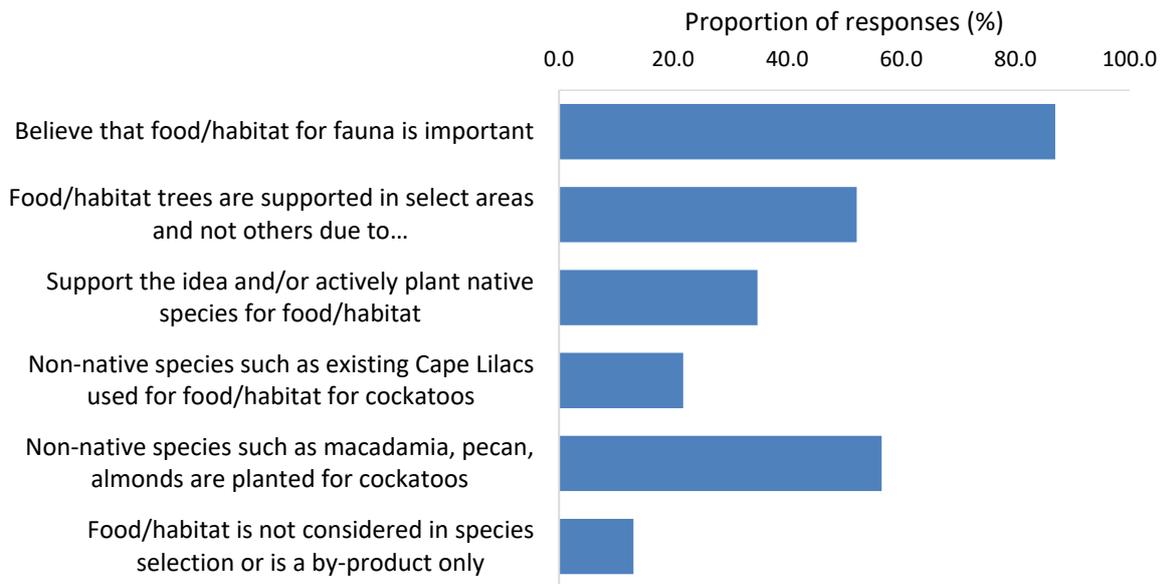


Figure 8. Summary of themes raised by LGA practitioners who spoke about urban forest as food/habitat for significant fauna (x-axis shows proportion of responses).

Resources for pollinators

Only around half of interviewees spoke about pollinators but of these, more practitioners admitted that pollinators were either not a factor influencing species selection at all, or were a by-product of selecting tree species for some other reason. While several practitioners indicated that certain species did attract pollinators like bees, it was not always clear whether this was the original intent or simply another benefit of that particular species. Of the interviewees who said that pollinators were not a consideration for species selection, a small number highlighted the risks associated with planting pollen-rich species with respect to residents with hay fever or allergies to bees.

Spatial segregation of urban forest functions

A closer look at spatial considerations reveals a difference between objectives/priorities for parks and POS, natural areas and ecological corridors, and residential verges. While some considerations overlap – for instance, providing habitat/forage for cockatoos occurs in both parks/POS and natural areas, and maximising canopy is a consideration in residential verges and parks – many considerations are only particular to certain areas. In natural areas, interviewees revealed certain priorities such as planting/propagating native species, avoiding weed ingress, and retaining old trees for habitat. Parks/POS were preferred places to plant/retain larger trees, including species considered problematic in other areas such as Cape Lilac and figs. Parks were also places to trial new species, and plant a variety of different species, including those not suitable for natural areas such as macadamias to be used as cockatoo food. In residential verges, the major considerations were suitability and/or fit given the spatial constraints (see Figure 10), and a desire to avoid species that might cause nuisance/risk.

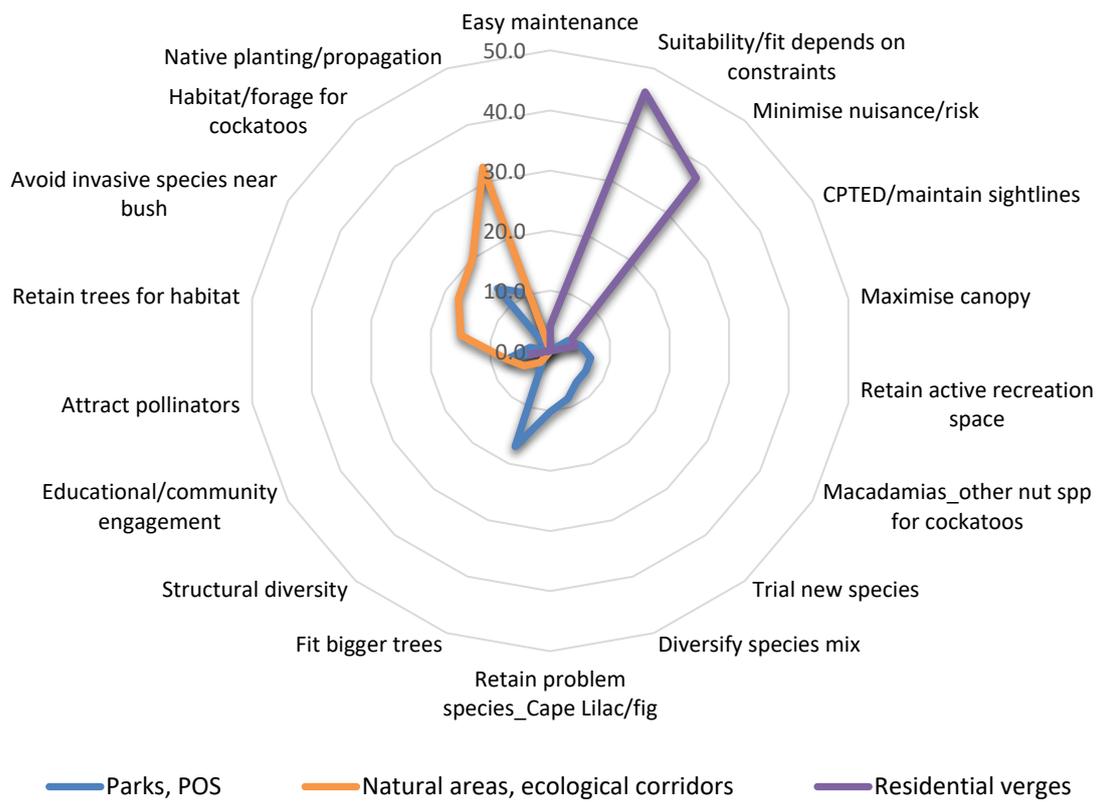


Figure 9. Urban forest priorities/considerations for different spatial locations, which suggests that the planning of urban forest functions is spatially segregated (axis shows proportion of responses).

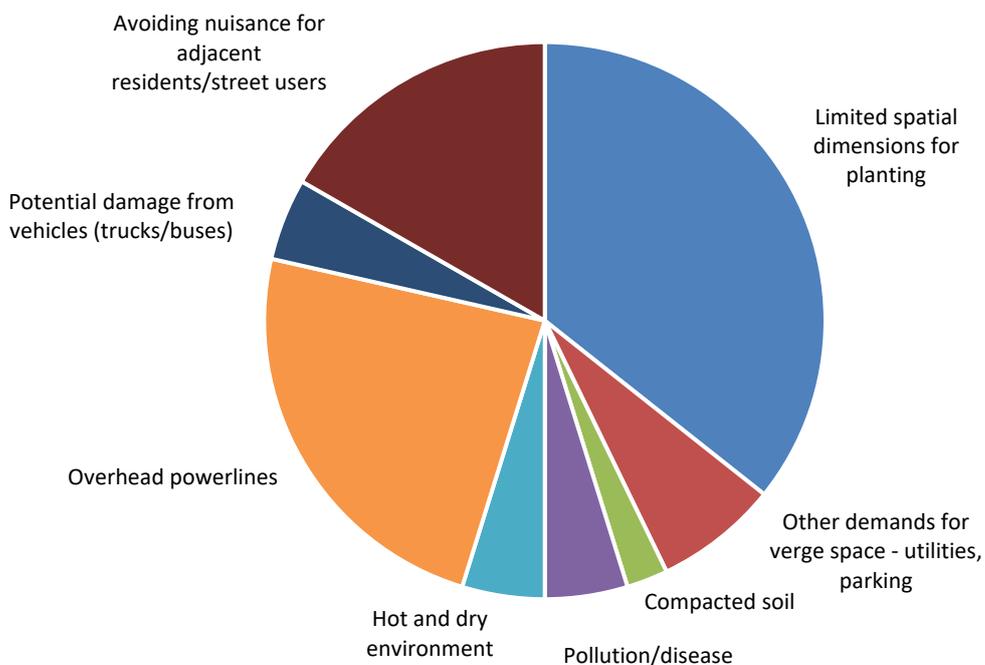


Figure 10. Main constraints in streetscapes mentioned by practitioners (shown as proportion of responses).

Factors influencing urban forest composition

We analysed interviews with the view to understand the different factors that influence the urban forest composition and therefore. We used the socio-ecological model recently proposed by Vogt (2020) to capture the multiple factors mentioned by practitioners.

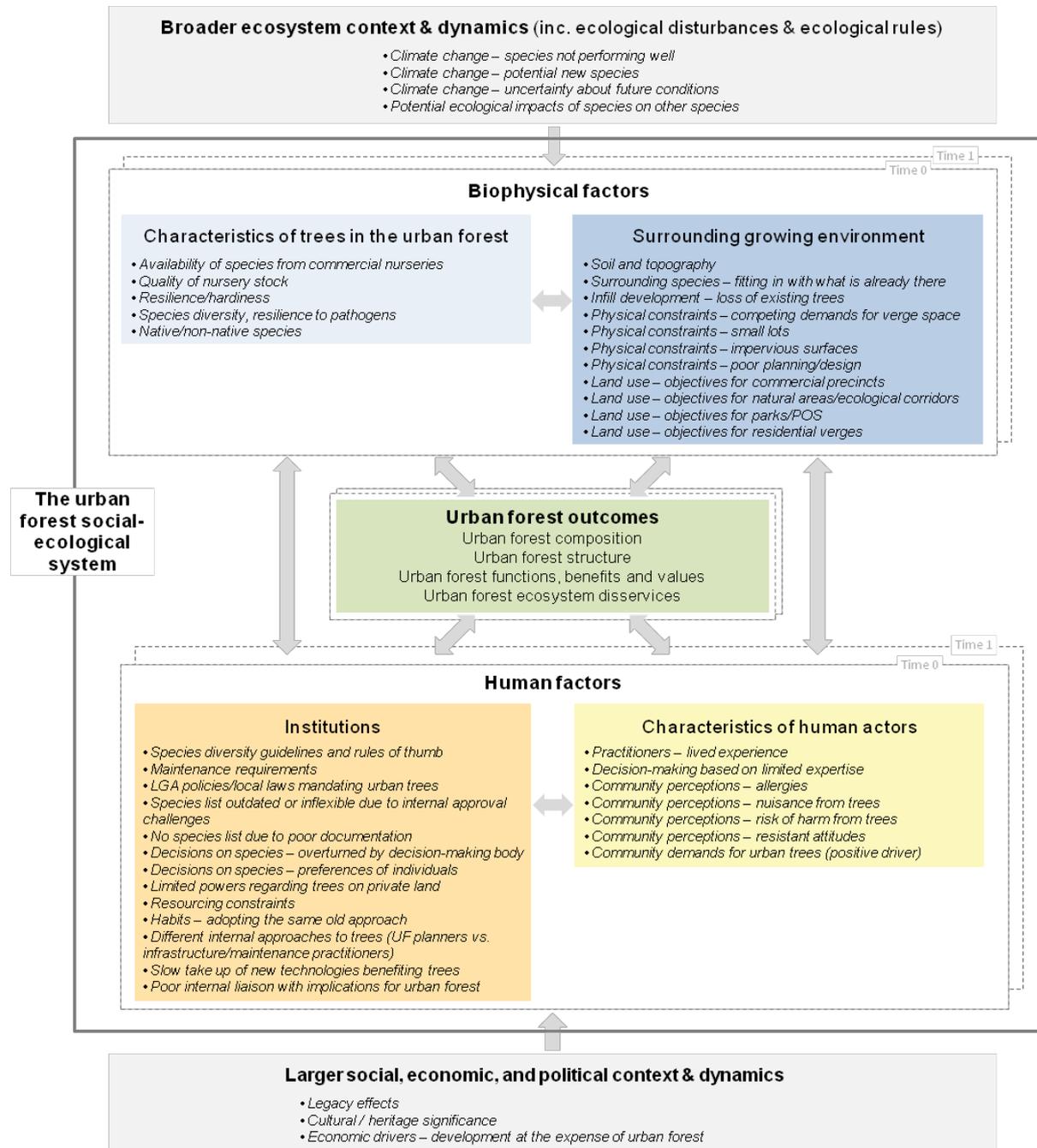


Figure 11. Factors influencing urban forest outcomes. This framework is adapted from Vogt 2020, with the sub-items within each main factor being the themes identified during the interviews with LGA practitioners.

Vogt's model considers that urban forest outcomes are influenced by four main core interacting factors relating to characteristics of the trees, the surrounding growing environment, institutions, and the characteristics of the human community. These core sets of

factors, their interactions, and observed outcomes are dynamic and may change over time. Additionally, they are influenced by the context and dynamics of the broader ecosystem, as well as the social, economic, and political systems within which urban forest exist. Figure 11 below presents an adaptation of the Vogt (2020) social-ecological model, with the themes captured during the interviews presented as sub-items.

Table 2 presents examples of quotes for each of the factors/themes and sub-themes identified during the interviews (organised based on the social-ecological model by Vogt 2020).

Key subthemes identified from the interview data	Examples (quotes)
Broader Ecosystem Context - Broader environmental factors	
Climate change - species not performing well	<p>“...a few of the maples we no longer plant. They’re too sensitive to the heat” (UF practitioner, IM6)ⁱ</p> <p>“we’ve definitely seen some impacts of decreasing rainfall, particularly some of the larger Tuarts do show signs, periodically, of ... they sort of senesce certain parts of their canopy” (Bio practitioner, OM1)</p>
Climate change – potential new species	<p>“We have started doing some trials where we’re bringing in different species down from Darwin and looking at planting them in areas and seeing how they cope with our Perth climate” (UF practitioner, IM4)</p>
Climate change – uncertainty about future conditions	<p>“None of us know what is going to happen. We know that certain species aren’t surviving now and we know that some are tracking okay but we don’t know that those ones tracking okay now are going to be okay in five years” (UF practitioner, IM2)</p> <p>“Climate change might change that so what did work might not work going forward so you have to try and factor that in and try and introduce species that potentially are going to be in a hotter climate type tree” (UF practitioner, IM3)</p>
Potential consequences for other species	<p>“if we’re bringing it back to urban forestry, how feasible is it to incorporate those species and should we even be doing that? Because a huge impact for black cockatoos is vehicle strike” (Bio practitioner, OM1)</p> <p>“In terms of street trees we make sure that we put the right sort of trees around natural areas. For example, we try to avoid <i>filicifolia</i> near natural areas because it hybridises so easily with the Marris. We avoid anything that has weedy tendencies that could become invasive” (UF practitioner, OM2)</p>
Characteristics of Trees	
Availability of species from commercial nurseries	<p>“In practice though, the selection is much more narrower than that because of the difficulty in obtaining many of the species. So there are problems with nurseries – the supply and so on. So we still tend to plant far too much of the same species purely because of the commercial nature of the nurseries and what they will grow and supply” (UF practitioner, IM6)</p> <p>“<i>Eucalyptus polyanthemos</i>, it used to be on there and there’s a few really nice ones around the City but just stock availability. Nurseries don’t grow it so there’s no point having it on your list” (UF practitioner, OM4)</p>
Quality of nursery stock	<p>“If we get a particular bad batch of trees for example - what we planted in the last two years, already 80% of it is dead. We’re replanting it. That is not because of temperature. It is not because of other... it is purely because it’s a separate problem. It is the poor quality of the nursery stock” (UF practitioner, IM6)</p>
Resilience/ hardiness	<p>“I just don’t see the point in having this system where you plant a tree and 10 years later it dies and you plant another one. You should pick something suitable for the location and stick to it” (UF practitioner, OM4)</p> <p>“Everything that we plant we try and get the most drought tolerant, the most tough, resilient, used to growing in concrete and crappy old soil, yeah. So that is top of our mind as to whether this tree is going to survive” (UF practitioner, IM3)</p>
Species diversity – resilience to pathogens	<p>“I think with the City with pathogens and that sort of the wider base of species that we can get, the better the likelihood of longevity of green and urban greening” (UF practitioner, OM4)</p>

Native/non-native species	<p>“Working in an urban realm you’ve got, and I’ve touched on this before, you’ve got microclimates or situations where you might not be able to accommodate a native tree in a very shaded location due to buildings or other structures” (UF practitioner, IM4)</p> <p>“When people ask me “why isn’t the City planting a lot more local native trees as street trees?”, that’s because you can count on the fingers of one hand – not two hands – one hand, the number of local native species that will do well in the constrained environment of a street verge” (Bio practitioner, IM3)</p> <p>“It’s accepted that we will try and plant native species where we can. Where there is no way around it like if a tree is going to be in lots of paving or you want big shade and you want winter sunlight, you need to look at deciduous trees and they’re not natives” (UF practitioner, IM1)</p>
Surrounding Growing Environment - Biophysical environment and urban settings	
Soil and topography	<p>“So you might actually get a species diversity map that might reflect how performance is changing across... because we do have change in soil types across here, plus we have super highly modified environments” (Bio practitioner, OM1)</p> <p>“Soil types around here – as I said we’ve got different suburbs and different soils. Not everything grows” (UF practitioner, IM5)</p>
Surrounding species – fitting in with what is already there	<p>“We do try to follow what the streets predominantly are planted in. If they’re predominantly oak trees, yes we’ll put oaks back even though they’re not indigenous but we’re trying to have some continuity with the historical landscaping that was inherited” (UF practitioner, IM1)</p> <p>“So we try and stay as close as we can to what’s in the street scapes so that there is some consistency but we find something else that might complement it, if we can’t match like for like” (Bio practitioner, IM6)</p>
Infill development – loss of existing trees	<p>“it’s been carved up and being filled in so we’re losing more of the canopy that you would have had on that one large property” (UF practitioner, OM1)</p> <p>“it maximises the lot and just about everything is cleared. And that seems to be the modern trend. So there are those challenges and lends very little space for the establishment of street trees and the preservation of trees that may have existed in the backyard” (Bio practitioner, IM3)</p>
Physical constraints – competing demands for verge space	<p>“particularly in the newer residential areas where the verge is being quite constrained now. They’re putting power, sewer, all those sorts of things in the verge” (Bio practitioner, OM1)</p> <p>“between the service corridor and the road reserve is filled with services, so there is no space for a tree there” (Bio practitioner, OM3)</p>
Physical constraints – small lots	<p>“the other issue is actually being able to plant trees in the new areas because the verges are so narrow” (UF practitioner, OM2)</p> <p>“up until two years ago, there was pretty much develop every square inch of your lots. I mean the lots are 200m² now! You can’t fit a ... Tuart on a 200m² block when the house is 180m²” (Bio practitioner, OM1)</p>
Physical constraints – impervious surfaces	<p>“we have almost no natural drainage so if it does rain, the City’s designed for water to be piped out. So any natural drainage is almost eliminated. That has a far, far greater impact than perhaps half a degree change in temperature – a far greater impact. It’s really the built form and how we design it. A hundred percent impervious in most areas ... We’re looking for species that can handle those harsh conditions” (UF practitioner, IM6)</p>
Physical constraints – poor planning/design	<p>“you then have the environment whereby you have two large crossovers or one large crossover that is impacting on the verge tree that is sitting there or it’s got to come down” (UF practitioner, OM1)</p>

	“someone sold the block, the block gets subdivided, they need access for crossovers for every single ... so every second tree goes or if we’re not careful they try to take all of them out” (UF practitioner, IM5)
Land use – objectives for commercial precincts	“You then look at your commercial precincts and they tend to have larger verges through there so you can have larger tree species with decent canopy through there. But then you have to be cognisant of those... like some of the larger infrastructure that are going down those roads which do overhang” (UF practitioner, OM1)
Land use – objectives for natural areas & ecological corridors	“natural areas we’re planting those species that are endemic to those areas” (Bio practitioner, OM1) “So for reserve areas, we try and put native connecting trees so that birds will go through those native trees” (UF practitioner, IM3)
Land use – objectives for parks/POS	“Parks you can fit bigger trees in than roadsides so we are going with that sort of direction” (UF practitioner, IM1) “We are trying to increase the diversity of our species planting in some of the parks where it’s suitable so I think there’s a lot more opportunity in parks” (UF practitioner, IM5)
Land use – objectives for residential verges	“our residential areas, a lot of them have only got really small verges so you can only put a certain type of plant there” (UF practitioner, IM5)
Urban forest desired outcomes	
Functions/benefits – aesthetics	“there’s always opportunity to add value and improve the visual environment and add a little more interest to make it more inviting to the public to sit on a park bench with a nice jacaranda tree. And I know that the jacaranda tree is not locally native to Western Australia... But why not use species such as that to invite interest and visitor appeal” (Bio practitioner, IM3)
Functions/benefits – attract pollinators	“Some of the heavily flowering species – Eucalyptus species – are better because they are pollinated by insects and birds so they’re actually better for that” (UF practitioner, IM1)
Functions/benefits – edible plants	“people want different things you know, with fruit on instead of peppermints, olives... they want something flowering or deciduous so we sort of balance it up” (UF practitioner, IM5)
Functions/benefits – food/habitat resource for fauna	“when we’re putting plants in the ground we’re always thinking about the cockatoos and a food source for them” (Bio practitioner, OM1) “the Carnaby’s black cockatoo came up as a species we should be looking to support. And yes we would try and plant native trees to support them wherever possible” (UF practitioner, IM4)
Functions/benefits – sense of place	“there are some suburbs where particular tree species is what defines the area” (UF practitioner, IM3)
Functions/benefits – shade and cooling	“Certainly you’re looking for something with a really wide canopy” (UF practitioner, IM2) “I think the majority of cooling that a tree provides is through its shade and the native species do provide shade as well but the broad-leaf deciduous provide that evaporative cooling effect as well. So we would definitely try, wherever possible, we would try to get those species in along those key gathering places. And particularly where they coincide with hot spots” (UF practitioner, IM4)
Institutions – Local government internal workings and politics	

Species diversity guidelines and rules of thumb	“the masterplan is looking at that diversity and what we’ve got an overabundance of where we’ve got an opportunity to actually choose a new species and what they should be and then guidelines on how we’re going to transition those areas that have got an overrepresentation of one particular family or species” (UF practitioner, IM3)
Maintenance requirements	“I know that our streetscapes/arboriculture team, they just want trees in the ground that’s easy for them and primarily that usually ends up being non-native species” (Bio practitioner, IM2) “Our parks and gardens team does like the deciduous trees but don’t like having to clean up after them. Plus it doesn’t make us popular with the civil side of things who have to clean out the drains when they get blocked with leaves” (UF practitioner, OM2)
LG policies/local laws mandating urban trees	“We do have street tree masterplans for all the new subdivisions so that tells operations what they should be planting in particular streets” (UF practitioner, OM2) “we did a bit of a targeted program in there and essentially went through and audited it all, identified everybody who had a tree and wrote to every single resident and just said “you’re getting a tree... and this is what it’s going to be” (UF practitioner, IM5)
Species list outdated or inflexible due to internal approval challenges	“Occasionally you may suggest a species. It has to go through a laborious process of being approved by Council. Generally it is then declined because of all kinds of unsubstantiated concerns but that’s enough for it to not go ahead. That’s again another reason why the palette is quite limited” (UF practitioner, IM6)
No species list due to poor documentation	“we have probably about three [species lists]. It depends who you talk with and which given days. That’s part of our challenge on our urban forest strategy at the moment. To try to get some alignment around what we will do and what we will accept, and try to tailor it to different places in the city as well...[The lists are] maybe on people’s computers or... we do really need to get on the same page” (Bio practitioner, OM3)
Decisions on species – overturned by decision-making body	“We say “well no, we need the tree because of this, this, this and this” and the resident goes, “well that’s not good enough, I want it gone now”. So they go to a Councillor and throw a tantrum, go to their local Member of Parliament and throw a tantrum and eventually someone at that level decides that “I can’t deal with this anymore, let’s take the tree out”” (UF practitioner, IM1) “One person arcs up, Councillor gets involved, backs the resident not to have a tree, next thing the trees are dropping from that project” (UF practitioner, IM3)
Decisions on species – preferences of individuals	“because our Director [likes jacarandas]. So if you want to get something across the line, you just chuck some jacarandas in. So that was the perception. There was no thought to these trees aren’t going to work, they’re the wrong species for the location. There was the thought of “if we have this nice artist’s concept with these purple flowers, that the Director will go tick”, which he did” (UF practitioner, OM4)
Limited powers regarding trees on private land	“There is an expectation I think that as a local government we can actually stop people from clearing trees on their own land. But there is no opportunity in planning law, no clearing permits required for residential land” (Bio practitioner, OM3) “So I think that until we saturate the public planting land, we don’t have all that much success engaging with private residents about their private vegetation” (UF practitioner, IM6)
Resourcing constraints	“You know funding is a critical element in a local authority. And now with COVID-19, the pandemic, that’s in everybody’s back pocket. And the easier things to take off are the ones that are the most tangible, which is the planting of trees” (UF practitioner, OM1)

Habits – adopting the same old approach	<p>“The ideal thing also would be to have proactive street tree management ...rather than just, “oh these people have asked for a tree, we’ll bung ‘em in and while we’re in the area we’ll see where else we can put some trees in there” and “we’ve bought some <i>filicifolias</i> – where can we stick those?”. “Oh we’ve got some of these ones left over, what suburb ... where can we stick these ones this year?” (UF practitioner, OM2)</p> <p>“over the years... a bit of a conservative type of attitude and that’s what I was touching on before – that the end product is really safe, overly safe selections of the tree” (UF practitioner, IM1)</p>
Different internal approaches to trees (UF planners vs. infrastructure/maintenance practitioners)	<p>“they see the trees as a piece of infrastructure to be managed, which means that removal is the easy option, rather than parks and gardens where removal is the last resort” (UF practitioner, OM2)</p> <p>“our ops team do some replacement planting sometimes if something has just died. Often they’ll just take it out and put the same thing back in. I have heard occasionally different things get put back in depending on how they’re feeling and what they’ve got available” (UF practitioner, IM3)</p>
Slow take up of new technologies benefiting trees	<p>“it took 8 or 9 years before I got engineers to actually accept permeable pavement - as a system... as a water reservoir underneath etc. and to create a legitimate root zone underneath the hard stand” (UF practitioner, IM6)</p>
Poor internal liaison with implications for urban forest	<p>“Somebody has approved plans but there’s a massive driveway going through trees. Why has nobody picked this up? Surely you can see that the tree’s in the way. “Oh it’s too late now, it’s all approved” so you get frustrations like that” (UF practitioner, IM3)</p>
Characteristics of the human community	
Practitioners – lived experience	<p>“Experience. Knowing what grows there. I pretty much know every single tree in the whole of the City so I can tell you. I know it grows there” (UF practitioner, IM5)</p> <p>“We’ve learnt from our mistakes and we’ve learnt from some of those species that we have put in over the years that they’re just not viable for the City and the other learnings we’ve gained from other local authorities enables us to make those informed decisions going forward” (UF practitioner, OM1)</p>
Decision-making based on limited expertise	<p>“There is almost nothing I can do without going through a chain of command. And that chain of command are not foresters. They don’t have that understanding. They are driven by politics - little, minute minor complaints with an elected member” (UF practitioner, IM6)</p> <p>“What I want to do and what they want to do is totally different and with all due respect to them, my Coordinator is a Parks Coordinator so when you’re talking turf and playing fields and things, he’s all over it. And he is very pro-tree but yeah, some of his suggestions for tree species sometimes...” (UF practitioner, OM4)</p>
Community perceptions – allergies	<p>“community have very strong views on what they feel is affecting their hayfever and whatnot” (UF practitioner, IM2)</p> <p>“It’s always a consideration in our species list to try to put forward trees that are not going to trigger people. Not always successful” (Bio practitioner, OM3)</p>
Community perceptions – nuisance from trees	<p>“[Box trees are] ugly, they’re not from here, they drop nuts. Jacarandas? People don’t like Jacarandas – they drop too many flowers, they drop too many leaves. Deciduous trees? Drop leaves. You know... the ones that cockatoos like – oh the cockatoos squawk and wake me up. Yeah.</p>

	Pretty much any tree you'll get a complaint about but the number of complaints are proportional really to the number of people with those trees on their verges" (UF practitioner, IM3)
Community perceptions – risk of harm from trees	"I suppose a negative of the large trees is they can drop branches or actually fall over, which can be a little bit scary" (Health practitioner, OM4)
Community perceptions – resistant attitudes	"you get the odd person who says, "I just don't like the tree". So you've got this real challenge ahead of you to try and manage that accordingly" (UF practitioner, OM1)
Community demands for urban trees (positive driver)	"We also respond obviously to community requests and we've had some really great strong communities that have requested actually can we go do street ... can we plant some trees in our park" (UF practitioner, OM4)
Broader social/economic/political context	
Legacy effects	"We've had also issues along streets where when the roads were originally put in 20-30 years ago, they're supposed to take all of the, sort of your hardened layers and all that from the street scape out of the medians and verges. But they didn't! So you've got a tree that is effectively containerised ... So we had them all the way down the median going there but the largest ones were like the height of that door. They were tiny ... And it was because we know there was road base underneath" (UF practitioner, OM4)
Cultural/heritage significance	"But people connect to, and certainly the Aboriginal connections, we ensure that those are well known in the City and we've got a number of scar trees that we preserve and are registered with heritage" (Health practitioner, IM2)
Economic drivers – development at the expense of urban forest	"I can see that the developer will try to make the most of their land in such a way that they're going to get the most benefit for themselves versus setting aside maybe larger portions of green space for trees that could have more canopy coverage. So the end result perhaps is less trees that develop big canopies versus species that might not have that coverage" (Health practitioner, OM2) "Most cities these days I think are just looking at the development side of things and there's a lot of clear felling of private vegetation so a lot of that" (UF practitioner, IM3)

Table 2. Examples of quotes for each of the factors/themes and sub-themes identified during the interviews (organised based on the social-ecological model by Vogt 2020).

Final remarks

This study aims to understand how biodiversity and human wellbeing considerations are being taken into account in the planning and management of the urban forest in Perth. While the results are only preliminary, interesting patterns have already emerged. These are the following:

- When asked about the importance of urban forest to their LGAs, canopy/shade and cooling was a major consideration for all practitioners. Biodiversity conservation was the next most important consideration for urban forest and biodiversity conservation practitioners. Health and wellbeing was mentioned more by health practitioners as was the importance of urban forest to sense of place/character and amenity/liveability.
- Shade and cooling and, to a much lesser extent sense of place, were functions actively considered in tree species selection. Biodiversity functions, including food/habitat for significant fauna and for pollinators, tended to be a secondary consideration or a by-product of selecting species for some other reason.
- Sense of place had different meanings for different practitioners. For some, it meant wayfinding – trees that help one locate where they are and that help enhance the character of a certain suburb. For others it meant connection to Western Australia environments – trees that bring the WA natural environment to the urban matrix.
- Although, when specifically asked about biodiversity functions, practitioners said that these were often a by-product, it became clear that those functions were actively considered in some parts of the urban landscape, including parks, POS and natural areas.
- While streetscapes present several biophysical constraints to tree planting and survival, it emerged that human factors, including LGAs internal ways of working and politics, as well as community perception, play a pivotal influence in urban forest management in these more contested urban spaces.
- It may be that the more contested urban spaces are, the harder it is to use an evidence-based approach to guide urban forest planning and management.

Urban settings are highly modified environments. Their complexity, both from the perspective of the built but also socio-political environment, the many stakeholders and end-users, mean that planning and managing urban forests for the delivery of multiple benefits is a fine balancing act. For a city such as Perth that is located within a region of unique biodiversity already feeling the effects of urbanisation but vulnerable to many other pressures as well, some of the patterns identified in this study highlight the challenge of managing such a critical resource and element of the city's own identity.

References

- ALVEY, A. A. 2006. Promoting and preserving biodiversity in the urban forest. *Urban Forestry & Urban Greening*, 5, 195-201.
- AUSTRALIAN BUREAU OF STATISTICS. 2020. *Regional Population Growth, Australia, 2018-19 (Cat. No. 3218.0)* [Online]. Canberra: Commonwealth of Australia. [Accessed].
- DEPARTMENT OF PLANNING, L. A. H. D. & WA PLANNING COMMISSION (WAPC) 2018. Perth and Peel @3.5 million. Perth: Government of Western Australia.
- DEPARTMENT OF PLANNING, L. A. H. D., WA PLANNING COMMISSION (WAPC) & WA LOCAL GOVERNMENT ASSOCIATION (WALGA) 2018. Better Urban Forest Planning: A guide to support the enhancement of urban forests in Western Australia. Perth: Government of Western Australia.
- HOPPER, S. D. & GIOIA, P. 2004. The Southwest Australian Floristic Region: conservation of a global hotspot of biodiversity. *Annual Review of Ecology, Evolution and Systematics*, 35, 623-650.
- JOHNSTONE, R. E., KIRKBY, T. & SARTI, K. 2017. The distribution, status, movements and diet of the forest red-tailed black cockatoo in the south-west with emphasis on the greater Perth region, Western Australia. *Western Australian Naturalist*, 193-219.
- LIVESLEY, S., MCPHERSON, E. & CALFAPIETRA, C. 2016. The urban forest and ecosystem services: Impacts on urban water, heat, and pollution cycles at the tree, street, and city scale. *Journal of environmental quality*, 45, 119-124.
- MYERS, N., MITTERMEIER, R. A., MITTERMEIER, C. G., FONSECA, G. A. B. & KENT, J. 2000. Biodiversity hotspots for conservation priorities. *Nature*, 403, 803-808.
- NOWAK, D. J., HIRABAYASHI, S., BODINE, A. & GREENFIELD, E. 2014. Tree and forest effects on air quality and human health in the United States. *Environmental Pollution*, 193, 119-129.
- ORDÓÑEZ, C., THRELFALL, C. G., KENDAL, D., HOCHULI, D. F., DAVERN, M., FULLER, R. A., VAN DER REE, R. & LIVESLEY, S. J. 2019. Urban forest governance and decision-making: A systematic review and synthesis of the perspectives of municipal managers. *Landscape and urban planning*, 189, 166-180.
- RAHMAN, M. A., STRATOPOULOS, L. M. F., MOSER-REISCHL, A., ZÖLCH, T., HÄBERLE, K.-H., RÖTZER, T., PRETZSCH, H. & PAULEIT, S. 2020. Traits of trees for cooling urban heat islands: A meta-analysis. *Building and Environment*, 170, 106606.
- SAO FRANCISCO PUBLIC WORKS 2014. Sao Francisco Urban Forest Plan. Phase 1 - Street trees. Sao Francisco, US.
- STOCK, W. D., FINN, H., PARKER, J. & DODS, K. 2013. Pine as fast food: foraging ecology of an endangered cockatoo in a forestry landscape. *PLoS One*, 8, e61145.
- THREATENED SPECIES SCIENTIFIC COMMITTEE 2016. Approved Conservation Advice for the Banksia Woodlands of the Swan Coastal Plain ecological community (In effect under the EPBC Act from 16-Sep-2016). Canberra: Department of the Environment and Energy.
- VALENTINE, L. E., RAMALHO, C. E., MATA, L., CRAIG, M. D., KENNEDY, P. L. & HOBBS, R. J. 2020. Novel resources: opportunities for and risks to species conservation. *Frontiers in Ecology and the Environment*, 18, 558-566.
- VOGT, J. 2020. Urban Forests as Social-Ecological Systems. In: GOLDSTEIN, M. I. & DELLASALA, D. A. (eds.) *Encyclopedia of the World's Biomes*. Elsevier.
- WA DEPARTMENT OF PLANNING LANDS AND HERITAGE 2020. Western Australia Tomorrow. Population Report No. 11. Medium Term Population Forecasts for Western Australia 2016 to 2031 and Sub-regions 2016 to 2031. Perth: Government of Western Australia.
- WILLIAMS, M. R., YATES, C. J., SAUNDERS, D. A., DAWSON, R. & BARRETT, G. W. 2017. Combined demographic and resource models quantify the effects of potential land-use change on the endangered Carnaby's cockatoo (*Calyptorhynchus latirostris*). *Biological Conservation*, 210, 8-15.
- WOOD, E. M. & ESAIAN, S. 2020. The importance of street trees to urban avifauna. *Ecological Applications*, 30.
-