Concepts and Questions

When cities are the last chance for saving species

Kylie Soanes[1,2*] and Pia E Lentini[2]

[1]*School of Ecosystem and Forest Sciences, The University of Melbourne, Parkville, Australia* [*]*(ksoanes@unimelb.edu.au);* [2]*School of BioSciences, The University of Melbourne, Parkville, Australia*

Running heads:

K Soanes and PE Lentini

Saving urban-restricted species

Urban environments are arguably among the most suitable targets for conservation science, as they represent opportunities to preserve both species and habitats under threat while at the same time allowing people to engage with nature. We highlight the need for conservation within urban environments using species whose recovery is entirely dependent on effective action within cities and towns. We identified 39 urban-restricted species in Australia and reviewed the advice guiding their conservation to address the question, "What does conservation look like when cities are the last chance for saving species?" We argue that in such circumstances securing land for conservation purposes cannot be relied upon; instead, species must be protected on lands not originally intended for conservation and urban communities must be involved in recovery actions. Ultimately, to achieve such outcomes, decision makers need to recognize the importance of urban ecosystems in the recovery of imperiled species.

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In a nutshell:

- Cities and towns can be important sites for conservation and engaging people with nature

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- Urban areas may also represent the last known places in which the populations of certain threatened taxa persist, and therefore represent the final opportunity to save such species from extinction
- Conserving urban-restricted threatened species requires looking beyond conventional conservation reserves and focusing instead on a variety of marginal habitats and land-use types
- These species also benefit when community members are aware of and engaged in local conservation-oriented initiatives
- The role of urban environments in species conservation is often overlooked, and should be incorporated into appropriate policy and recovery strategies

The field of conservation biology has progressed considerably from its traditional focus on "wild" areas that are far removed from human impacts (Soulé 1985; Kareiva and Marvier 2012). It is increasingly recognized that areas of intensive human land use often coincide with biodiversity hotspots, threatened species, and ecosystems of conservation concern (Ives *et al*. 2016; Kowarik and von der Lippe 2018; Threlfall and Kendal 2018) and that conservation action in such landscapes is critical (Miller and Hobbs 2002; Dunn *et al*. 2006; Blaustein 2013). This need is perhaps most pronounced when a species' entire global distribution is contained within a landscape modified by human activity. For example, McDonald *et al*. (2008) predicted that 24 rare species on the IUCN Red List of Threatened Species – each of which at that time was restricted to a single remaining known population – would be affected by urban growth by the year 2030.

However, conservation research and action in urban landscapes is still an emerging field (Shwartz *et al*. 2014; Kowarik and von der Lippe 2018). Given that "urban" is often considered to be the opposite of "natural", urban environments suffer from a persistent stigma (Klaus 2013; Salomon Cavin 2013; Soanes *et al*. 2018) and are routinely cast as the antithesis of wilderness or viewed as a "lost cause" (Miller and Hobbs 2002; Kowarik 2018). This perception is reflected in policies that focus on large, intact, or undisturbed habitat remnants (Tulloch *et al*. 2016; Kendal *et al*. 2017); in conservation planning exercises that exclude urban areas from consideration; and in the behavior and attitudes of land managers and the wider community (Stokes *et al*. 2010; Olive 2014). Consequently, conservation opportunities within areas characterized by high-density human populations, built environments, and small habitat remnants are underexploited and poorly understood. Yet urban environments are

arguably among the most fitting targets for conservation science, because they provide opportunities to conserve species and ecosystems under threat while simultaneously offering people a chance to engage with and benefit from nature (Soulé 1985; Kareiva and Marvier 2012).

Here, we reinforce the importance of urban conservation by highlighting the plight of urban-restricted threatened species, for which urban environments represent the last chance for them to be conserved within their natural range. We identified 39 nationally threatened species whose current distribution is wholly restricted to Australian cities and towns (Figure 1) and reviewed the national advice documents guiding their recovery (hereafter referred to as "recovery documents"; Panel 1; WebTable 1) to address the question, "What does conservation look like when cities are the last chance for saving species?"

Securing urban land for conservation is rarely feasible

A central tenet of conservation is to secure critical habitat through protected areas or conservation covenants, particularly in cases where remaining habitat is scarce. However, space in cities is limited. While securing land for conservation purposes was recommended for 18 of the 39 urban-restricted threatened species included in our review, this will be difficult to achieve in the urban realm. Existing green spaces are under pressure from urban infill (Haaland and van den Bosch 2015; Hedblom *et al*. 2017), whereas those on the fringes of cities are vulnerable to urban sprawl (Jim 2004; Seto *et al*. 2011). The recovery documents for many urban-restricted threatened species acknowledged this reality, noting that the high development potential (and therefore the possible purchasing cost) of the lands on which the species occurred placed many sites at considerable risk. Perhaps tellingly, residential and industrial developments were implicated in the decline of 26 species; the recovery documents for these species described the loss of entire populations to development, even at sites that contained the last known population. The Frankston spider-orchid (*Caladenia robinsonii*) and small golden moths orchid (*Diuris basaltica*), for instance, were believed to have gone extinct when the sites supporting the last known populations at the time were developed, and at least 15 other species occur on lands zoned for future development (Panel 2). Although this seems a dire prognosis for urban-restricted threatened species, conservation actions are not limited to the formal protection of sites. A suite of approaches are available to enhance urban environments, provide resources critical to species, and expand the range of suitable habitats available through the principles of "biodiversity sensitive" urban design or conservation development (Milder 2007; Ikin *et al*. 2015; Garrard *et al*. 2018). If securing land for

conservation is a luxury that can be extended to only a few urban-restricted threatened species, then alternative approaches must be embraced in order to prevent their extinction.

Urban land not intended for conservation plays a critical role

Embracing a broader view of the land types suitable for conservation opens up new avenues for threatened species recovery in urban environments. Australia's 39 urban-restricted threatened species are not limited to remnants of native vegetation or reserves but instead occur across diverse land-use types (Figure 2), including roadsides (11 species), private land (10 species), military lands (5 species), schools (4 species), golf courses (4 species), railways and utility easements (4 species), airports (3 species), cemeteries (1 species), and hospitals (1 species). One of the largest known populations of the spiked rice flower (*Pimelea spicata*) persists at a golf course, while a species of guinea-flower (*Hibbertia puberula glabrescens*) is known only from the grounds of an airport. The ongoing survival and recovery of these species must therefore incorporate actions on lands not originally intended for conservation. For example, golf course managers are working to conserve the spiked rice flower, enhancing habitat and raising awareness among golfers and nearby residents. But the potential for conservation gains in unconventional landscapes is often unrecognized (Shwartz *et al*. 2014; Kowarik and von der Lippe 2018). For many urban-restricted threatened species, sites that are small, that have been highly modified, or that no longer support remnant vegetation are rarely prioritized – yet these are often the areas where species recovery efforts must occur. Opportunities range from protection and sympathetic management of existing populations to active habitat enhancement and establishment of new populations. Achieving positive conservation outcomes without compromising the original use of a space depends on strong partnerships among a range of stakeholders to balance competing land-use needs and identify "win–win" scenarios (Rosenzweig 2003; Aronson *et al*. 2014). Although this can be challenging, emerging success stories highlight the potential rewards (eg Colding *et al*. 2006; Ramírez-Restrepo *et al*. 2017). Conversely, failing to recognize the value of unconventional spaces can lead to the degradation and destruction of important habitats (Panel 3).

Engaged communities can provide powerful support

While being close to a large human population can pose many risks to threatened species inhabiting urban environments (eg Panel 3), such proximity can also be an advantage if the human community is aware of and engaged in local conservation action. Many of the urban-restricted threatened species that we identified benefit from community conservation efforts.

For example, the local community has been instrumental in the management and recovery of the Frankston spider-orchid, with more than 1300 volunteer-hours invested in improving habitat for the species' last known population. Such engagement might not have been possible, and would certainly have been logistically difficult, had this population occurred in a more remote location. Although most recovery documents (for 29 species) included broad aims to raise awareness of a species' plight, simply informing the public is inadequate, and active measures to increase their sense of ownership, participation, and stewardship are needed (Andersson *et al*. 2014). The urban-restricted threatened species presented here have great potential to engender community care for *their* unique threatened species. For example, the Canberra spider-orchid (*Caladenia actensis*), Sydney Plains greenhood (*Pterostylis saxicola*), and Bomaderry zieria (*Zieria baeuerlenii*) are all named for the area in which they occur, and therefore are prime candidates as flagship species to capitalize on community pride and sense of place through "adoption" by local schools, businesses, or community groups. In some cases the precise location of a threatened species must be kept secret for its own protection (Panel 4; Lindenmayer and Scheele 2017), but the potential benefits of engaging local communities and inspiring stewardship in species conservation are substantial (Andersson *et al*. 2014; Shwartz *et al*. 2014). As one example, a crowd-funding campaign in 2016 to "Save the sexy scented orchids" raised more than AU$18,000 from 144 contributors to support the conservation of the urban-restricted sunshine diuris (*Diuris fragrantissima*) and small golden moths orchid. Moreover, fostering community stewardship for urban threatened species may also serve to increase people's interest in and experiences with nature, resulting in improved human health and well-being (Dunn *et al*. 2006; Shanahan *et al*. 2015), which are often the goal of environmental policy. Finally, a consideration of the perspectives of Indigenous communities was notably absent: approximately one-half of the recovery documents (for 18 of the 39 species) identified intent to consult with Indigenous peoples, while none described their involvement in existing conservation activities. Formal recognition of the values, perspectives, and knowledge of Indigenous communities would not only enrich conservation outcomes for these threatened species but would also acknowledge and encourage the inclusion of cultural rights in urban conservation practices (Leiper *et al*. 2018).

Decision makers must be aware of the role of cities in species conservation

Urban environments are not always on the conservation "radar" even when they are essential to a species' management and recovery. Research has repeatedly demonstrated that

biodiversity conservation in urban environments receives insufficient attention in government policy and municipal planning (Miller *et al*. 2009; de Oliveira *et al*. 2011; Olive and Minichiello 2013). Indeed, we contend that many planners, land managers, and conservation scientists would be surprised to learn that a threatened species' distribution could be entirely urban, or that focusing conservation efforts on unconventional sites is critical to their persistence. In fact, it was rarely apparent in the recovery documents we reviewed that a species was urban-restricted. Several species lost key populations because the relevant authorities or land managers were unaware of either the species occurrence or the importance of the urban site (Panels 2 and 3). Under these circumstances, the conservation of urban-restricted threatened species is relegated to the realm of damage control as opposed to recovery. People cannot protect what they are not aware of and will not protect that which seems unimportant. The widespread lack of awareness of urban conservation issues is a key factor limiting the conservation and recovery of urban-restricted species, but this deficiency could be remedied in several ways. First and foremost, the documents and policy guiding a species' recovery should clearly acknowledge the urban nature of its distribution; second, the presence of specialist biodiversity conservation staff on planning or local government teams can improve the degree to which biodiversity conservation is considered in decision making (Miller *et al*. 2009; Stokes *et al*. 2010). Steps such as these would bring threatened species recovery into the urban planning discourse, work to encourage proactive conservation in future developments, and act as a "red flag" to regulators to prevent further losses.

Conclusions

Urban environments represent the last chance to conserve particular species within their natural ranges, and therefore are essential pieces of the conservation puzzle. The benefits of urban conservation are clear: improved outcomes for species protection and recovery in line with international commitments (de Oliveira *et al*. 2011), and improved opportunities for the growing urban human population to connect with nature (Kowarik 2018). Globally, opportunities for cities to play important roles in threatened species conservation abound. For example, approximately 22% of occurrences of federally listed endangered plant species in the US are located in the country's 40 largest metropolitan areas, which encompass just 8.4% of the country's total land area (Schwartz *et al*. 2002); urban gardens are critical to the resurgence of endangered *Eumaeus* butterfly species in Mexico (Ramírez-Restrepo *et al*. 2017); and several cities, such as Cape Town, South Africa, and Ioannina, Greece, contain biodiversity hotspots and support high species endemism (Rebelo *et al*. 2011; Kantsa *et al*.

2013). Our review of urban-restricted threatened species in Australia reaffirms that urban environments not only present opportunities for biodiversity but are also a necessary component of conservation. Ideally, conservation approaches would consider the importance of urban landscapes *before* cities become a species' last chance, not simply as an emergency response but as part of a proactive conservation strategy. However, success depends on adopting novel conservation and urban design strategies, embracing opportunities and partnerships on unconventional lands, and fostering community stewardship. Ultimately, this requires clear recognition of the role that urban environments play in a species' survival and future recovery at all levels of decision making. When cities are the last chance for saving species, the conservation community must stop disregarding the urban environment and start putting conservation science into practice in the places where it is most needed.

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Supporting Information

Additional, web-only material may be found in the online version of this article at

Figure captions

Figure 1. The location of urban-restricted threatened species across Australia. The number of species per location is indicated in parentheses. Selected examples have been illustrated, including (counterclockwise from top left) fringed keraudrenia (*Keraudrenia exastia*; critically endangered); western swamp tortoise (*Pseudemydura umbrina*; critically endangered); Carbunup king spider-orchid (*Caladenia procera*; critically endangered); Kilsyth South spider-orchid (*Caladenia* sp Kilsyth South; critically endangered); Milford leek-orchid (*Prasophyllum milfordense*; critically endangered); Ginninderra peppercress (*Lepidium ginninderrense*; vulnerable); Nielsen Park she-oak (*Allocasuarina portuensis*; endangered); downy wattle (*Acacia pubescens*; vulnerable); and angle-stemmed myrtle (*Gossia gonoclada*; endangered). Artwork by E Pirtle.

Figure 2. Urban-restricted threatened species rely on a variety of land-use types, such as airports (*Hibbertia puberula glabrescens*; top left), golf courses (spiked rice flower, *Pimelea spicata*; top right), railway verges (sunshine diuris, *Diuris fragrantissima*; bottom left), and roadsides (seaforth mintbush, *Prostanthera marifolia*; bottom right). Artwork by E Pirtle.

Figure 3. Caley's grevillea (*Grevillea caleyi*), an endangered urban-restricted species, continues to experience incremental population losses due to development.

Photo credit:
I Mamott

SPS: please insert Figure 3 into Panel 2

Figure 4. For many years, Angus's onion orchid (*Microtis angusii*) was known from only a single roadside in Sydney, yet this has not prevented the site from being subjected to various disturbances.

Photo credit:
M Macrae

SPS: please insert Figure 4 into Panel 3

Figure 5. The wavy-leaved smokebush (*Conospermum undulatum*) is now restricted to the city of Perth, but its precise location is kept secret.

Photo credit:
M Brundrett

SPS: please insert Figure 5 into Panel 4

Panel 1. Australia's urban-restricted threatened species

To identify urban-restricted threatened species in Australia, we downloaded all point records for species listed as threatened ("vulnerable", "endangered", and "critically endangered") under the Australian Environment Protection and Biodiversity Conservation Act 1999 (as of February 2016) from the Atlas of Living Australia website (www.ala.org.au). These points were cross-checked against polygons representing 99 Australian towns and cities with populations of >10,000 people and for which the land character is predominantly described as "urban" (for details, see Ives *et al*. [2016]). This allowed us to create a short-list of species for which all points recorded after the year 2000 fell within or close to the boundary of an urban area. We then verified the validity of these records based on (1) the associated spatial uncertainty (eg the observer or source), (2) descriptions of the species' distribution presented in the Australian Government's Species Profiles and Threats Database (Department of the Environment and Energy 2017), and (3) spatial data provided by the Australian Government representing the "known" ranges of the species (described in Ives *et al*. [2016]). This resulted in a list of 39 urban-restricted species (37 plants and two animals) that occurred in only one or two Australian cities or towns (WebFigure 1; WebTable 1). We then reviewed the suite of documents used to guide the conservation for each species (referred to as "recovery documents"; accessed through the Department of the Environment and Energy 2017) to ascertain the degree to which policy guidance supports their conservation within urban environments and to identify key themes guiding urban conservation. A full description of the documents reviewed for each species is available in WebTable 1. Urban-restricted species covered a range of taxonomic groups that included orchids, flowering shrubs, large trees, a tortoise, and a snail. The most commonly identified threats were urbanization and habitat loss (89%), invasive weeds (88%), and altered fire regimes (76%).

Panel 2. Urban environments are critical to meeting conservation commitments

The threat of future development to conservation is exemplified by the case of Caley's grevillea (*Grevillea caleyi*; Figure 3), an urban-restricted threatened species targeted for recovery by 2020 in the Australian Government's *Threatened Species Strategy* (Department of the Environment and Energy 2015). To date, more than 85% of this species' habitat has been cleared for urban growth, with many remaining populations occurring on land zoned for development. Key challenges identified in the recovery documents include the high development value of the land on which the species occurs, a lack of awareness of the

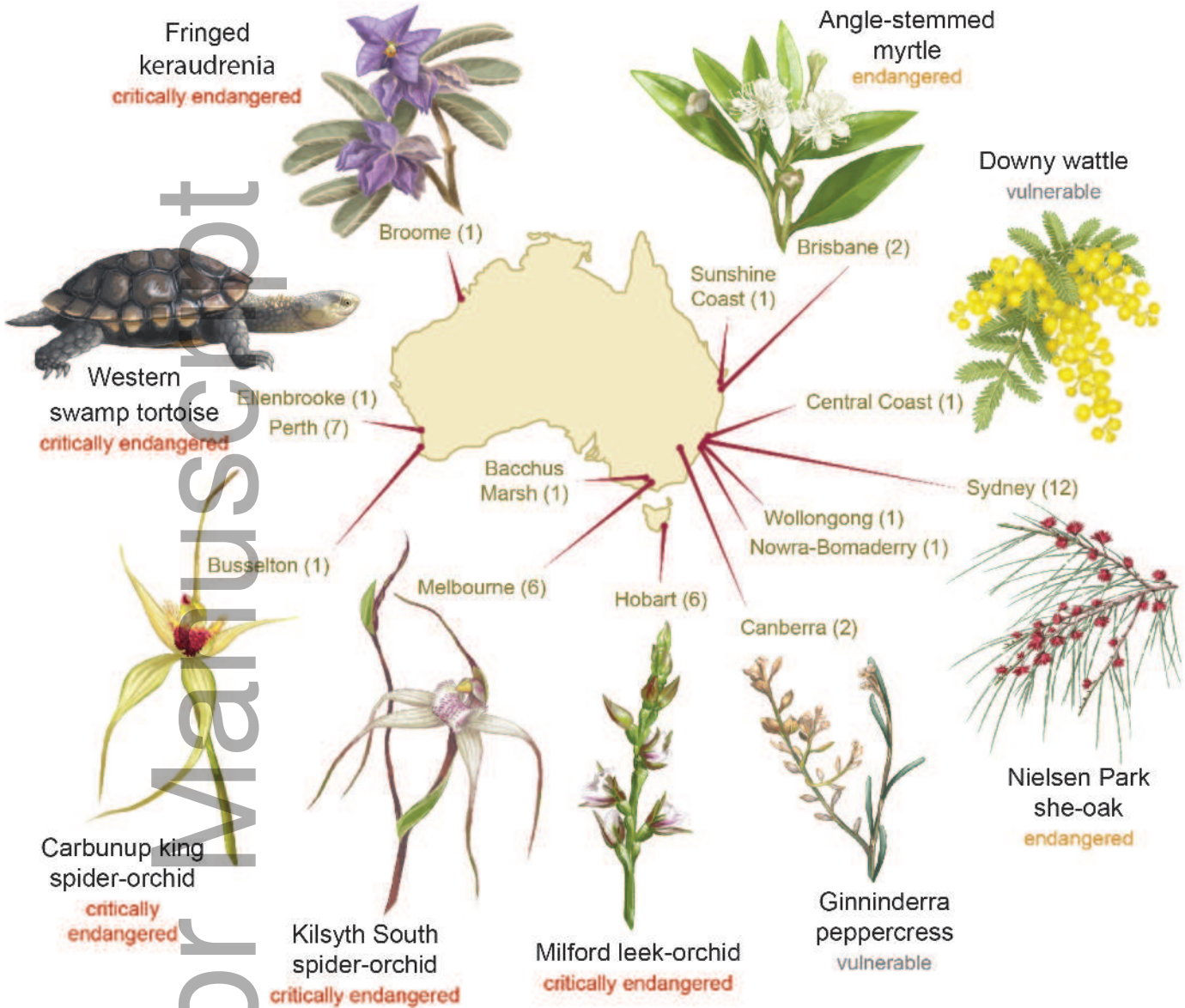
species' existence, and a lack of consultation among relevant authorities prior to development, resulting in the incremental loss of *G caleyi* populations.

Panel 3. A series of unfortunate events

Conserving threatened species on land not intended for conservation can be challenging, with entire populations seemingly one poor decision or stroke of bad luck away from extinction. A roadside in northern Sydney that supported the only known population of Angus's onion orchid (*Microtis angusii*; Figure 4) was subjected to numerous events that threatened the species' persistence. In 1989, the entire orchid population was covered with 10 metric tons of sand when a utility company used the area to dump their construction fill, and mitigation attempts involved a bulldozer and a high-pressure hose. Later, the site was used to accommodate a telephone company's portable toilets. In 1999 the site was also heavily grazed during the flowering season, and, later in 2007, sprayed with herbicide. The future survival of urban-restricted threatened species depends on collaboration and communication among key stakeholders to avoid preventable incidents such as these.

Panel 4. Loved to death?

A unique challenge for many urban-restricted threatened species is the threat of being "loved to death". One-quarter of the species on our list had been subjected to or were at risk of illegal collection or deliberate destruction. Negative side effects of eager naturalists seeking rare plants in urban reserves include trampling, disturbing plants or microclimates while attempting to obtain photographs, and even removing entire plants (Ballantyne and Pickering 2012). In such cases, urban conservation must strike a balance between raising awareness to promote conservation (Tulloch *et al*. 2018) and maintaining secrecy to protect specific locations (Lindenmayer and Scheele 2017). For example, the recovery documents for the wavy-leaved smokebush (*Conospermum undulatum*; Figure 5) highlight actions to promote awareness through an education campaign but also recommend that the location of the species be kept secret from the general public.



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