



Minerva Access is the Institutional Repository of The University of Melbourne

Author/s:

Soanes, K;Sievers, M;Chee, YE;Williams, NSG;Bhardwaj, M;Marshall, AJ;Parris, KM

Title:

Correcting common misconceptions to inspire conservation action in urban environments

Date:

2019-04-01

Citation:

Soanes, K., Sievers, M., Chee, Y. E., Williams, N. S. G., Bhardwaj, M., Marshall, A. J. & Parris, K. M. (2019). Correcting common misconceptions to inspire conservation action in urban environments. *Conservation Biology*, 33 (2), pp.300-306. <https://doi.org/10.1111/cobi.13193>.

Persistent Link:


<https://hdl.handle.net/11343/270910>

License:

[CC BY](#)



Correcting common misconceptions to inspire conservation action in urban environments

Kylie Soanes ^{1,2*} Michael Sievers,^{1,2} Yung En Chee,¹ Nicholas S. G. Williams,¹ Manisha Bhardwaj,² Adrian J. Marshall,¹ and Kirsten M. Parris¹

¹School of Ecosystem and Forest Sciences, The University of Melbourne, VIC, 3010, Australia

²School of BioSciences, The University of Melbourne, VIC, 3010, Australia

Abstract: *Despite repeated calls to action, proposals for urban conservation are often met with surprise or scepticism. There remains a pervasive narrative in policy, practice, and the public psyche that urban environments, although useful for engaging people with nature or providing ecosystem services, are of little conservation value. We argue that the tendency to overlook the conservation value of urban environments stems from misconceptions about the ability of native species to persist within cities and towns and that this, in turn, hinders effective conservation action. However, recent scientific evidence shows that these assumptions do not always hold. Although it is generally true that increasing the size, quality, and connectivity of habitat patches will improve the probability that a species can persist, the inverse is not that small, degraded, or fragmented habitats found in urban environments are worthless. In light of these findings we propose updated messages that guide and inspire researchers, practitioners, and decision makers to undertake conservation action in urban environments: consider small spaces, recognize unconventional habitats, test creative solutions, and use science to minimize the impacts of future urban development.*

Keywords: cities, conservation policy, novel habitats, patch size, urban biodiversity, urban conservation, urban green space

Corrección de Ideas Erróneas para Inspirar Acciones de Conservación en Ambientes Urbanos

Resumen: *A pesar de las repetidas llamadas a actuar, las propuestas para la conservación urbana con frecuencia se enfrentan a reacciones de sorpresa o escepticismo. Todavía existe una narrativa penetrante en la política, la práctica y el psique del público que dicta que los ambientes urbanos, aunque sean útiles para comprometer a las personas con la naturaleza o para proporcionar servicios ambientales, tienen poco valor para la conservación. Argumentamos que la tendencia de pasar por alto el valor para la conservación de los ambientes urbanos surge de las ideas erróneas sobre la habilidad que tienen las especies nativas para persistir dentro de ciudades y pueblos y que esto, en cambio, impide la acción efectiva de la conservación. A pesar de esto, la evidencia científica reciente muestra que estas suposiciones no siempre se sostienen. Aunque casi siempre es verdad que incrementar el tamaño, la calidad y la conectividad de los fragmentos de hábitat mejorará la probabilidad de que una especie pueda persistir, lo contrario, que los hábitats fragmentados, degradados y pequeños que se encuentran en los ambientes urbanos son inútiles, no lo es. A la luz de estos hallazgos proponemos mensajes actualizados que guíen e inspiren a los investigadores, practicantes y a los tomadores de decisiones a emprender acciones de conservación en ambientes urbanos: considerar espacios pequeños, reconocer hábitats poco convencionales, probar con soluciones creativas, y utilizar la ciencia para minimizar los impactos de desarrollos urbanos futuros.*

Palabras Clave: área verde urbana, biodiversidad urbana, ciudades, conservación urbana, hábitats novedosos, políticas de conservación, tamaño de fragmento

*email ksoanes@unimelb.edu.au

Article impact statement: *Conserving native biodiversity is both important and achievable in urban environments. Paper submitted February 18, 2018; revised manuscript accepted July 13, 2018.*

This is an open access article under the terms of the Creative Commons Attribution License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

摘要: 尽管人们一再呼吁要采取城市保护行动,然而却常常对相关提案表示诧异或怀疑。在政策制定、实践行动和公众心理中仍存在一种普遍的认识,即城市环境虽然有助于人们亲近自然并提供生态系统服务,但其保护价值微乎其微。我们认为,这种忽视城市环境保护价值的倾向来源于对本地物种在城市和乡镇间续存能力的误解,而这反过来又阻碍了有效的保护行动。然而,最近的科学证据表明这些种种假设并不总是成立。虽然通常情况下增加生境斑块的大小、提高其质量和连接度可以提高物种续存的可能性,但反过来看,并不是说退化或碎片化的小面积生境在城市环境中就毫无价值。鉴于以上发现,我们建议更新这些指导和激励研究者、实践者和决策者采取城市环境保护行动的信息,应考虑小尺度空间的保护、认识非传统生境、尝试创新性解决方案,并利用科学知识来减少未来城市发展带来的影响。【翻译:胡怡思;审校:聂永刚】

城市: 保护政策, 新生境, 斑块大小, 城市保护, 城市多样性, 城市绿地

Introduction

The value of urban environments for the conservation of native species can be surprisingly contentious. Recent global analyses indicate urban areas are expanding and are a major cause of biodiversity loss (Seto et al. 2012; Aronson et al. 2014). Urban areas encompass a wide range of ecosystems, include regions of high native biodiversity, and are inhabited by rare and threatened species (Schwartz et al. 2002; Rebelo et al. 2011; Kantsa et al. 2013; Ives et al. 2016). Given that urban areas are expanding and these areas contain important native species, it follows that protecting and promoting biodiversity in such areas should be critical. Yet in practice, progress is slow and uneven. Despite repeated calls to action in the scientific literature (e.g., Miller & Hobbs 2002; Rosenzweig 2003; Dunn et al. 2006), suggestions for urban biodiversity conservation are still met with surprise, doubt, or scepticism (Semlitsch & Bodie 1998; Sander-son & Huron 2011; Salomon Cavin 2013). It seems there remains a pervasive narrative in policy, practice, and the public psyche that urban environments, while useful for engaging people with nature or providing ecosystem services, are of little conservation value. We argue that this tendency to undervalue urban environments stems from misconceptions about the ability of native species to persist within cities and towns. Common assumptions are that the urban environment is not suitable for conservation in the long term due to the quantity and of remnant habitat, an inevitable extinction debt, and unmanageable impacts from human activity. These threats are real and the concerns legitimate, but they do not preclude meaningful conservation. We examined how these misconceptions are increasingly at odds with the findings of recent urban biodiversity research and propose updated narratives to inspire and guide conservation action.

Misconceptions Underpinning Negative Views of Urban Conservation

Most conservation strategies and policies place a premium on large, high-quality, well-connected patches of remnant vegetation with a low prevalence of threats. However, such patches are rare in the urban realm and

this invites the view that urban environments are inherently worse for conservation. The small, heavily modified habitats so common to urban environments are rarely protected by policy, vulnerable to death by 1000 cuts (Tulloch et al. 2016), and often considered expendable (Semlitsch & Bodie 1998). In other cases, urban areas are overlooked altogether. For example, it is not unusual for large-scale conservation prioritization or planning exercises to exclude urban areas from consideration or assign them a low conservation value a priori (Moilanen et al. 2005). Policy makers, land managers, and conservation practitioners are, thus, reluctant to invest limited conservation dollars and effort in an area deemed to be of high risk, low value, and with a low probability of success (Miller & Hobbs 2002; Sanderson & Huron 2011; Olive 2014). But are these assumptions about urban environments supported by current research?

Although it is generally true that increasing the size, quality, and connectivity of habitat patches will improve the probability that a species can persist, the inverse is not that small, degraded, or fragmented habitats are worthless. Prugh et al.'s (2008) meta-analytic study of >1,000 bird, mammal, reptile, amphibian, and invertebrate population networks on 6 continents demonstrated that patch area and isolation are surprisingly poor predictors of occupancy for most species. Further, a recent review found little evidence to support the notion that habitat fragmentation per se has a negative impact on biodiversity (Fahrig 2017). The role of the intervening matrix in providing resources and facilitating movement is now well recognized, to the point that it can no longer simply be referred to as nonhabitat (Franklin & Lindenmayer 2009; Driscoll et al. 2013).

Turning to organisms themselves, we note that the life-history traits of a species, such as reproductive requirements, generation time, and mobility, can play a large role in determining the likelihood of persistence in urban environments. For example, large patches of habitat may not be required to support the persistence of small plants with limited dispersal ability (McCarthy et al. 2006). Other factors such as adaptedness and adaptive potential (i.e., phenotypic or behavioral plasticity) also influence the capacity of organisms to exploit and survive in urban environments (McDonnell & Hahs 2015).

These research insights do not support the lost cause narrative so frequently applied to urban environments. The mismatch between common understanding (among researchers and practitioners) and recent scientific evidence (e.g., Norton et al. 2016) suggests the need for revised messages to guide conservation action in cities. We devised 4 key messages to correct common misconceptions that limit urban conservation action, identified examples from the growing body of research on urban biodiversity, and considered how policy and practice could be updated to make these actions more effective. In short, urban conservation must consider small spaces, recognize unconventional habitats, test creative solutions, and use science to minimize the impacts of future urban development.

Messages to Inspire Urban Conservation

Valuing Small Urban Spaces

Small urban spaces can support and sustain populations of native species. Even very small landscape elements, such as solitary trees (Stagoll et al. 2012) or ponds (Calhoun et al. 2014; Hill & Wood 2014), provide critical habitat resources. Many species can inhabit small patches in altered landscapes by adjusting their home range and behaviors or by taking advantage of resources that lie beyond the patch within the urban matrix (Shochat 2004; Wright et al. 2012). In some cases, small urban habitats support comparable populations and species diversity to nonurban areas, are critical to the persistence of local populations, and enhance regional diversity. For example, a comprehensive analysis of 80 ponds in Switzerland not only found little evidence for taxon-specific species-area relationships, but the number of species in a set of small ponds was greater than a single large pond of comparable total area (Fig. 1a) (Oertli et al. 2002). Similarly, an assessment of a network of urban grasslands in Australia showed that small grasslands contained unique species not found in larger reserves and thus contributed to the overall biodiversity of the landscape (Kendal et al. 2017). The potential for cumulative biodiversity gains to be made through the management of multiple small urban spaces may also better attract conservation initiatives led by local government or community groups with limited resources. Protecting and enhancing small landscape elements in urban environments through appropriate policy and decision making is therefore critical to maintain native biodiversity in cities and towns.

Recognizing Unconventional Habitats

Urban areas abound with unconventional habitats: areas originally created for human use that can provide im-

portant habitat or resources for native biodiversity. The potential for unconventional habitats is wonderfully diverse, ranging from large spaces such as brownfields, golf courses, and cemeteries (Colding & Folke 2009; Threlfall et al. 2015; Gilchrist et al. 2016; Gallo et al. 2017) to smaller pockets such as roadsides or cavities within buildings and infrastructure (Fig. 1b & 1c) (Ray & George 2009; Maclagan et al. 2018). For example, wetlands constructed to trap sediments and treat stormwater before it enters creeks and rivers are readily inhabited by a variety of native species (Hassall & Anderson 2015). Similarly, public and private gardens often provide novel resources that might not otherwise exist in the urban landscape (Davies et al. 2009; Schlaepfer et al. 2011; Chalker-Scott 2015). For example, 2 endangered butterfly species (genus *Eumaeus*) persist in urban areas of Mexico and the United States because their favored cycad host plant is a popular ornamental species in urban gardens, parks, and roadsides (Ramírez-Restrepo et al. 2017), while the number and diversity of urban street trees has contributed to large range extensions of the nationally vulnerable grey-headed flying fox (*Pteropus poliocephalus*) in several Australian cities (Williams et al. 2006). In Singapore, smooth-coated otters (*Lutrogale perspicillata*) have reestablished resident populations along the urban coastline after a 30-year absence (Fig. 1d) (Theng & Sivasothi 2016). Managing native biodiversity in unconventional habitats will depend on developing strong partnerships and collaborations with a range of stakeholders, along with careful evaluation of the species use of, and survival in, these spaces to ensure that they are beneficial in the long term and do not function as ecological traps (Schlaepfer et al. 2002). Ultimately though, managers in urban environments can achieve conservation gains in spaces that might otherwise be ignored by considering how a wider variety of spaces and land uses can benefit biodiversity.

Developing Creative Actions

There is a growing need to intentionally create conditions for nature to thrive in urban environments (Rosenzweig 2003; Sanderson & Huron 2011). This includes actions to minimize human-wildlife conflict, reduce mortality rates, or provide resources that might otherwise be lacking in urban areas (e.g., feeding or nesting sites). Changing the type of street lighting, for example, can reduce the impact of artificial light on nocturnal species (Lewanzik & Voigt 2017), novel collars can reduce predation of urban wildlife by domestic cats (Calver et al. 2007), and artificial cavities can provide suitable nesting sites for wildlife (Bender et al. 2016; Griffiths et al. 2018). Artificial structures, such as wildlife bridges and tunnels, can also be used to overcome barriers to movement created by urban infrastructure (Fig. 1e). Rope bridges installed as part of the Urban Monkeys Program in southern Brazil



Photo: © Beat Oertli.



Photo: Jesse Kurylo CC-BY-NC-SA 4.0.



Photo: Caragh Threfall CC-BY-NC-SA 4.0.



Photo: Jeffrey Teo CC-BY-NC-SA 4.0.



Photos: © Marcel Huijser.

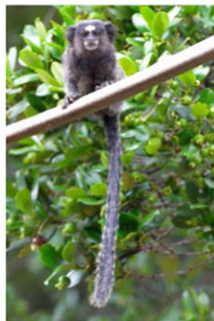


Photo: Nicholas Williams CC-BY-NC-SA 4.0.

Figure 1. Important components of urban conservation from top left to bottom right: (a) small areas that provide habitat, pond in Geneva, Switzerland; (b) a benevolent matrix, road verge with common dandelion and a butterfly in Melbourne, Australia; (c) novel nesting structures, bats roosting under a motorway in Sydney, Australia; (d) highly modified habitats, smooth-coated otters reestablished along an urban coastline in Singapore; (e) creative solutions, road-crossing structures to improve connectivity for primates in urban Brazil; and (f) novel landscapes, green roof with an insect hotel.

provided safe passage for brown howler monkeys (*Alouatta guariba clamitans*), porcupine (*Spiggurus villosus*), and white-eared opossum (*Didelphis albiventris*) across urban roads (Teixeira et al. 2013). More recently, conservation scientists have advocated for bolder initiatives in urban environments, such as creating habitats on built infrastructure (Fig. 1f) (Williams et al. 2014), recognizing the value of novel ecosystems (Hobbs et al. 2009; Kowarik 2011), and restoring species through reintroduction and translocation (Watson & Watson 2015). If creative actions are to become routine management practice, they must be accompanied by a thorough and coordinated evaluation of their effectiveness. Studies that take an experimental approach to evaluating new methods (e.g., Lewanzik & Voigt 2017; Griffiths et al. 2018; Soanes et al. 2018) will help build an evidence base for urban conservation that can guide managers and practitioners to apply creative practices that promote biodiversity in cities and towns.

Minimizing Future Impacts

In rethinking urban conservation, one must also have future urban development squarely in sight. Urbanization is accelerating through expansion (Jim 2004; Seto et al. 2011) and densification (Haaland & van den Bosch 2015; Hedblom et al. 2017); the majority of urban growth is predicted to occur in biodiversity hotspots in Asia and Africa (Seto et al. 2012; Schneider et al. 2015; UN DESA 2018). This will place increasing pressure on natural environments, including direct impacts in situ such as habitat loss, fragmentation, and degradation, as well as indirect impacts that can propagate a city's ecological footprint far beyond the immediate area of development (Rees & Wackernagel 1996). Although minimizing the ecological footprint of cities requires sustainability innovations beyond the scope of this paper, we point to existing scientific evidence and tools that can be used to build urban environments with improved outcomes

for biodiversity. At the landscape scale, systematic conservation planning can be used to plan new cities or suburbs that maximize development objectives while avoiding areas critical for biodiversity. This approach explicitly quantifies and maps the relative biodiversity value of different areas across the landscape (e.g., based on modeled habitat quality for target species or expert opinion) to help stakeholders visualize, understand, and deliberate the merits of multiple urban development options. Bekessy et al. (2012) showed how systematic planning methods can aid the community and decision makers in making informed and intelligent trade-offs, such as designating development zones in areas of lower biodiversity value in western Melbourne (Australia), while Ground et al. (2016) illustrated the value of urban and peri-urban conservation planning for the conservation of grassland ecosystems in the rapidly urbanizing eThekweni Municipal Area of South Africa. Analyses that take approaches that address the entirety of a landscape will be particularly useful for comparing oft-debated development alternatives, such as sharing versus sparing (Lin & Fuller 2013) or sprawl versus densification (Rebello et al. 2011), as well as the likely outcomes of sustainable development initiatives (Güneralp et al. 2017). Considering the site-level scale (i.e., 10s to 1000s of m²), evidence-based urban design principles can help develop neighborhoods that are more sensitive to biodiversity (Milder 2007; Hostetler & Drake 2009; Marshall 2013; Ikin et al. 2015; Garrard et al. 2017). These synthesize the growing body of urban ecological research to show how protecting and increasing habitat, facilitating dispersal and ecological processes, minimizing threats, and promoting positive human-nature interactions can all be achieved in urban developments. Garrard et al. (2017) proposed the framework of “biodiversity sensitive urban design” to guide the implementation of these principles during the design, construction, and postconstruction phases of development. A key advantage of this approach is the emphasis on ensuring the persistence of biodiversity within urban settings, in contrast to offsetting (Chee 2015), which is unlikely to provide fair and adequate compensation for urbanization impacts (Coker et al. 2018). Regardless of scale, achieving better biodiversity outcomes in future urban developments will depend on forward planning and collaborative partnerships among the community, government, ecologists, planners, engineers, and architects to develop co-created solutions.

Urban Conservation as an Opportunity Waiting

“The problems of urban conservation are not insurmountable, but success requires a careful start” (Dearborn & Kark 2010). Conserving native biodiversity is both important and achievable in cities and towns. There is mount-

ing evidence that the public support the conservation of urban biodiversity (Chen & Jim 2010; Olive 2014), including the importance of interactions with charismatic species (Savard et al. 2000; Stokes et al. 2010) and the cultural significance of urban nature (Cocks & Dold 2006; MSDI 2015). The presence of biodiversity in cities also benefits people, improving human health and well-being through connection to nature (Fuller et al. 2007; Shanahan et al. 2015). Community engagement can also boost biodiversity conservation: the urban community was instrumental in documenting the return of smooth-coated otters to Singapore (Theng & Sivasothi 2016) and the installation and monitoring of rope bridges for arboreal mammals in southern Brazil (Teixeira et al. 2013). However, long-held perceptions that undervalue urban environments undermine opportunities for conservation. The messages we have highlighted here update the narrative of urban biodiversity conservation, enabling researchers, policy makers, planners, and practitioners to act based on scientific evidence and tools. Although our list is not exhaustive, tackling current misconceptions represents a critical step in moving toward effective conservation action in urban spaces. Recognizing the value of small spaces and unconventional habitats for native species, and the potential for creative conservation opportunities, opens up new avenues for managers in urban environments and will lead to better conservation outcomes. For example, researchers in Germany reintroduced grassland species to urban wasteland lots, taking advantage of these small, unconventional spaces to create novel ecosystems that met conservation goals (Fischer et al. 2013). Further, the experimental approach allowed the researchers to identify the most successful and cost-effective methods and provide guidance to land managers. Re-imagining urban spaces and proposed developments as opportunities for conservation gains rather than as derelict, modified habitats helps empower communities and local managers to take positive actions for biodiversity on a local scale. In this way, overcoming the misconceptions that constrain conservation action for biodiversity in urban environments will ultimately benefit both urban biodiversity and the humans that live in cities.

Acknowledgments

This paper was developed through discussions by the Urban Biodiversity, Ecology and Conservation group in the School of Ecosystem and Forest Sciences at the University of Melbourne. K.S. is supported by the Clean Air and Urban Landscapes Hub and the Threatened Species Recovery Hub of the National Environmental Science Program. Y.E.C. is supported by the Melbourne Waterway Research Practice Partnership funded by Melbourne Water.

Literature Cited

- Aronson MF, La Sorte FA, Nilon CH, Katti M, Goddard MA, Lepczyk CA, Warren PS, Williams NS, Cilliers S, Clarkson B. 2014. A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proceedings of the Royal Society B* **281**:20133330.
- Bekessy SA, White M, Gordon A, Moilanen A, McCarthy MA, Wintle BA. 2012. Transparent planning for biodiversity and development in the urban fringe. *Landscape and Urban Planning* **108**:140–149.
- Bender J, Fidino M, Limbrick K, Magle S. 2016. Assessing nest success of black-capped chickadees (*Poecile atricapillus*) in an urban landscape using artificial cavities. *The Wilson Journal of Ornithology* **128**:425–429.
- Calhoun AJK, Jansujwicz JS, Bell KP, Hunter Jr ML. 2014. Improving management of small natural features on private lands by negotiating the science-policy boundary for Maine vernal pools. *Proceedings of the National Academy of Sciences of the USA* **111**:11002–11006.
- Calver M, Thomas S, Bradley S, McCutcheon H. 2007. Reducing the rate of predation on wildlife by pet cats: the efficacy and practicability of collar-mounted pounce protectors. *Biological Conservation* **137**:341–348.
- Chalker-Scott L. 2015. Nonnative, noninvasive woody species can enhance urban landscape biodiversity. *Arboriculture and Urban Forestry* **41**:173–186.
- Chee YE. 2015. Principles underpinning biodiversity offsets and guidance on their use. Pages 51–59 in van der Ree R, Smith DJ, Grilo C, editors. *Handbook of road ecology*. Wiley and Blackwell, London.
- Chen WY, Jim C. 2010. Resident motivations and willingness-to-pay for urban biodiversity conservation in Guangzhou (China). *Environmental Management* **45**:1052–1064.
- Cocks M, Dold A. 2006. Cultural significance of biodiversity: The role of medicinal plants in urban African cultural practices in the Eastern Cape, South Africa. *Journal of Ethnobiology* **26**:60–81.
- Coker ME, Bond NR, Chee YE, Walsh CJ. 2018. Alternatives to biodiversity offsets for mitigating the effects of urbanization on stream ecosystems. *Conservation Biology* **32**:789–797.
- Colding J, Folke C. 2009. The role of golf courses in biodiversity conservation and ecosystem management. *Ecosystems* **12**:191–206.
- Davies ZG, Fuller RA, Loram A, Irvine KN, Sims V, Gaston KJ. 2009. A national scale inventory of resource provision for biodiversity within domestic gardens. *Biological Conservation* **142**:761–771.
- Dearborn DC, Kark S. 2010. Motivations for conserving urban biodiversity. *Conservation Biology* **24**:432–440.
- Driscoll DA, Banks SC, Barton PS, Lindenmayer DB, Smith AL. 2013. Conceptual domain of the matrix in fragmented landscapes. *Trends in Ecology & Evolution* **28**:605–613.
- Dunn RR, Gavin MC, Sanchez MC, Solomon JN. 2006. The pigeon paradox: Dependence of global conservation on urban nature. *Conservation Biology* **20**:1814–1816.
- Fahrig L. 2017. Ecological responses to habitat fragmentation *per se*. *Annual Review of Ecology, Evolution, and Systematics* **48**:1–23.
- Fischer LK, Lippe MVD, Rillig MC, Kowarik I. 2013. Creating novel urban grasslands by reintroducing native species in wasteland vegetation. *Biological Conservation* **159**:119–126.
- Franklin JF, Lindenmayer DB. 2009. Importance of matrix habitats in maintaining biological diversity. *Proceedings of the National Academy of Sciences of the USA* **106**:349–350.
- Fuller RA, Irvine KN, Devine-Wright P, Warren PH, Gaston KJ. 2007. Psychological benefits of greenspace increase with biodiversity. *Biology Letters* **3**:390–394.
- Gallo T, Fidino M, Lehrer EW, Magle SB. 2017. Mammal diversity and metacommunity dynamics in urban green spaces: implications for urban wildlife conservation. *Ecological Applications* **27**:2330–2341.
- Garrard GE, Williams NS, Mata L, Thomas J, Bekessy SA. 2017. Biodiversity sensitive urban design. *Conservation Letters* **11**:e12411.
- Gilchrist A, Barker A, Handley JF. 2016. Pathways through the landscape in a changing climate: the role of landscape structure in facilitating species range expansion through an urbanised region. *Landscape Research* **41**:26–44.
- Griffiths SR, Lentini PE, Semmens K, Watson SJ, Lumsden LF, Robert KA. 2018. Chainsaw-carved cavities better mimic the thermal properties of natural tree hollows than nest boxes and log hollows. *Forests* **9**:235.
- Ground LE, Slotow R, Ray-Mukherjee J. 2016. The value of urban and peri-urban conservation efforts within a global biodiversity hotspot. *Bothalia-African Biodiversity & Conservation* **46**:1–10.
- Güneralp B, Lwasa S, Masundire H, Parnell S, Seto KC. 2017. Urbanization in Africa: challenges and opportunities for conservation. *Environmental Research Letters* **13**:015002.
- Haaland C, van den Bosch CK. 2015. Challenges and strategies for urban green-space planning in cities undergoing densification: a review. *Urban Forestry & Urban Greening* **14**:760–771.
- Hassall C, Anderson S. 2015. Stormwater ponds can contain comparable biodiversity to unmanaged wetlands in urban areas. *Hydrobiologia* **745**:137–149.
- Hedblom M, Andersson E, Borgström S. 2017. Flexible land-use and undefined governance: From threats to potentials in peri-urban landscape planning. *Land Use Policy* **63**:523–527.
- Hill MJ, Wood PJ. 2014. The macroinvertebrate biodiversity and conservation value of garden and field ponds along a rural-urban gradient. *Fundamental and Applied Limnology* **185**:107–119.
- Hobbs RJ, Higgs E, Harris JA. 2009. Novel ecosystems: Implications for conservation and restoration. *Trends in Ecology & Evolution* **24**:599–605.
- Hostetler M, Drake D. 2009. Conservation subdivisions: A wildlife perspective. *Landscape and Urban Planning* **90**:95–101.
- Ikin K, Le Roux DS, Rayner L, Villaseñor NR, Eyles K, Gibbons P, Manning AD, Lindenmayer DB. 2015. Key lessons for achieving biodiversity-sensitive cities and towns. *Ecological Management and Restoration* **16**:206–214.
- Ives CD, et al. 2016. Cities are hotspots for threatened species. *Global Ecology & Biogeography* **25**:117–126.
- Jim CY. 2004. Green-space preservation and allocation for sustainable greening of compact cities. *Cities* **21**:311–320.
- Kantsa A, Tschulin T, Junker RR, Petanidou T, Kokkini S. 2013. Urban biodiversity hotspots wait to get discovered: the example of the city of Ioannina, NW Greece. *Landscape and Urban Planning* **120**:129–137.
- Kendal D, Zeeman BJ, Ikin K, Lunt ID, McDonnell MJ, Farrar A, Pearce LM, Morgan JW. 2017. The importance of small urban reserves for plant conservation. *Biological Conservation* **213**:146–153.
- Kowarik I. 2011. Novel urban ecosystems, biodiversity, and conservation. *Environmental Pollution* **159**:1974–1983.
- Lewanzik D, Voigt CC. 2017. Transition from conventional to light-emitting diode street lighting changes activity of urban bats. *Journal of Applied Ecology* **54**:264–271.
- Lin BB, Fuller RA. 2013. Sharing or sparing? How should we grow the world's cities? *Journal of Applied Ecology* **50**:1161–1168.
- Maclagan SJ, Coates T, Ritchie EG. 2018. Don't judge habitat on its novelty: Assessing the value of novel habitats for an endangered mammal in a peri-urban landscape. *Biological Conservation* **223**:11–18.
- Marshall A. 2013. Start with the grasslands: design guidelines to support native grasslands in urban areas. *Victorian National Parks Association, Melbourne*.
- McCarthy MA, Thompson CJ, Williams NSG. 2006. Logic for designing nature reserves for multiple species. *The American Naturalist* **167**:717–727.
- McDonnell MJ, Hahs AK. 2015. Adaptation and adaptedness of organisms to urban environments. *Annual Review of Ecology, Evolution, and Systematics* **46**:261–280.

- Milder JC. 2007. A framework for understanding conservation development and its ecological implications. *AIBS Bulletin* **57**:757–768.
- Miller JR, Hobbs RJ. 2002. Conservation where people live and work. *Conservation Biology* **16**:330–337.
- Moilanen A, Franco AM, Early RI, Fox R, Wintle B, Thomas CD. 2005. Prioritizing multiple-use landscapes for conservation: methods for large multi-species planning problems. *Proceedings of the Royal Society of London B: Biological Sciences* **272**:1885–1891.
- MSDI (Monash Sustainable Development Institute). 2015. *Caring for country: an urban application*. MSDI, Melbourne.
- Norton BA, Evans KL, Warren PH. 2016. Urban biodiversity and landscape ecology: patterns, processes and planning. *Current Landscape Ecology Reports* **1**:178–192.
- Oertli B, Joye DA, Castella E, Juge R, Cambin D, Lachavanne JB. 2002. Does size matter? The relationship between pond area and biodiversity. *Biological Conservation* **104**:59–70.
- Olive A. 2014. Urban awareness and attitudes toward conservation: A first look at Canada's cities. *Applied Geography* **54**:160–168.
- Prugh LR, Hodges KE, Sinclair ARE, Brashares JS. 2008. Effect of habitat area and isolation on fragmented animal populations. *Proceedings of the National Academy of Sciences of the USA* **105**:20770–20775.
- Ramírez-Restrepo L, Koi S, MacGregor-Fors I. 2017. Tales of urban conservation: *Eumaeus* butterflies and their threatened cycad host-plants. *Urban Ecosystems* **20**:375–378.
- Ray JG, George J. 2009. Phytosociology of roadside communities to identify ecological potentials of tolerant species. *Journal of Ecology and the Natural Environment* **1**:184–190.
- Rebello A, Holmes P, Dorse C, Wood J. 2011. Impacts of urbanization in a biodiversity hotspot: conservation challenges in metropolitan Cape Town. *South African Journal of Botany* **77**:20–35.
- Rees W, Wackernagel M. 1996. Urban ecological footprints: why cities cannot be sustainable—and why they are a key to sustainability. *Environmental Impact Assessment Review* **16**:223–248.
- Rosenzweig ML. 2003. Reconciliation ecology and the future of species diversity. *Oryx* **37**:194–205.
- Salomon Cavin J. 2013. Beyond prejudice: Conservation in the city. A case study from Switzerland. *Biological Conservation* **166**:84–89.
- Sanderson EW, Huron A. 2011. Conservation in the city. *Conservation Biology* **25**:421–423.
- Savard J-PL, Clergeau P, Mennechez G. 2000. Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning* **48**:131–142.
- Schlaepfer MA, Runge MC, Sherman PW. 2002. Ecological and evolutionary traps. *Trends in Ecology & Evolution* **17**:474–480.
- Schlaepfer MA, Sax DF, Olden JD. 2011. The potential conservation value of non-native species. *Conservation Biology* **25**:428–437.
- Schneider A, Mertes C, Tatem A, Tan B, Sulla-Menashe D, Graves S, Patel N, Horton J, Gaughan A, Rollo J. 2015. A new urban landscape in East-Southeast Asia, 2000–2010. *Environmental Research Letters* **10**:034002.
- Schwartz MW, Jurjavic NL, O'Brien JM. 2002. Conservation's disenfranchised urban poor. *BioScience* **52**:601–606.
- Semlitsch RD, Bodie JR. 1998. Are small, isolated wetlands expendable? *Conservation Biology* **12**:1129–1133.
- Seto KC, Fragkias M, Güneralp B, Reilly MK. 2011. A meta-analysis of global urban land expansion. *PLoS ONE* **6** (e23777) <https://doi.org/10.1371/journal.pone.0023777>.
- Seto KC, Güneralp B, Hutyrá LR. 2012. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences of the USA* **109**:16083–16088.
- Shanahan DF, Lin BB, Bush R, Gaston KJ, Dean JH, Barber E, Fuller RA. 2015. Toward improved public health outcomes from urban nature. *American Journal of Public Health* **105**:470–477.
- Shochat E. 2004. Credit or debit? Resource input changes population dynamics of city-slicker birds. *Oikos* **106**:622–626.
- Soanes K, Taylor AC, Sunnucks P, Vesk PA, Cesarini S, der Ree R. 2018. Evaluating the success of wildlife crossing structures using genetic approaches and an experimental design: Lessons from a gliding mammal. *Journal of Applied Ecology* **55**:129–138.
- Stagoll K, Lindenmayer DB, Knight E, Fischer J, Manning AD. 2012. Large trees are keystone structures in urban parks. *Conservation Letters* **5**:115–122.
- Stokes DL, Hanson MF, Oaks DD, Straub JE, Ponio AV. 2010. Local land-use planning to conserve biodiversity: planners' perspectives on what works. *Conservation Biology* **24**:450–460.
- Teixeira FZ, Printes RC, Fagundes JCG, Alonso AC, Kindel A. 2013. Canopy bridges as road overpasses for wildlife in urban fragmented landscapes. *Biota Neotropica* **13**:117–123.
- Theng M, Sivasothi N. 2016. The smooth-coated otter *Lutrogale perspicillata* (Mammalia: Mustelidae) in Singapore: Establishment and expansion in natural and semi-urban environments. *IUCN Otter Spec. Group Bull* **33**:37–49.
- Threlfall CG, Walker K, Williams NS, Hahs AK, Mata L, Stork N, Livesley SJ. 2015. The conservation value of urban green space habitats for Australian native bee communities. *Biological Conservation* **187**:240–248.
- Tulloch AIT, Barnes MD, Ringma J, Fuller RA, Watson JEM. 2016. Understanding the importance of small patches of habitat for conservation. *Journal of Applied Ecology* **53**:418–429.
- UN DESA (Department of Economic and Social Affairs). 2018. 2018 revision of world urbanization prospects. UN, New York.
- Watson DM, Watson MJ. 2015. Wildlife restoration: Mainstreaming translocations to keep common species common. *Biological Conservation* **191**:830–838.
- Williams NS, Lundholm J, Scott MacIvor J. 2014. Do green roofs help urban biodiversity conservation? *Journal of Applied Ecology* **51**:1643–1649.
- Williams NSG, McDonnell MJ, Phelan GK, Keim L, van der Ree R. 2006. Range expansion due to urbanisation: increased food resources attract grey-headed flying-foxes (*Pteropus poliocephalus*) to Melbourne. *Austral Ecology* **31**:190–198.
- Wright JD, Burt MS, Jackson VL. 2012. Influences of an urban environment on home range and body mass of Virginia opossums (*Didelphis virginiana*). *Northeastern Naturalist* **19**:77–86.

