

## Article

# Nature-Positive Design and Development: A Case Study on Regenerating Black Cockatoo Habitat in Urban Developments in Perth, Australia

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**Abstract:** The benefits of ecosystem services to cities are well documented; for example, water-sensitive urban design to mitigate stormwater flows and purify run-off, the cooling benefits provided by tree shade, and psychological benefits of urban greening. Cities tend to displace nature, and in urban environments where nature exists it tends to be as highly altered ecosystems. This paper sets out how it is possible to regenerate nature in cities. We outline the principles of how to do this through a study on a new regenerative urban development in Perth, Australia, where urban planning is intended to support the regeneration of a bioregional habitat within the city. The authors, drawn from sustainability, property development and ecological backgrounds, describe how urban regeneration can potentially facilitate the regeneration of endemic habitat within the city. This builds on the original ecosystem functionality to provide an urban ecosystem that enables biodiversity to regenerate. Perth lies on the Swan Coastal Plain, a biodiversity hotspot; it is home to 2.1 million people and numerous endemic species such as the endangered Black Cockatoo. Low reproduction rates and habitat loss through agricultural clearing, fire and urban expansion have greatly reduced the Black Cockatoo's range and this continuing trend threatens extinction. However, the charismatic Black Cockatoos enjoy passionate support from Perth's citizens. This paper describes a range of strategies whereby new urban development could potentially harness the popularity of the iconic Black Cockatoo to build momentum for urban habitat regeneration (for the cockatoos and other species) on the Swan Coastal Plain. The strategies, if systematically operationalised through urban planning, could allow city-scale ecological gain. The authors suggest a framework for nature-positive design and development that offers multiple benefits for human and non-human urban dwellers across scales, from individual gardens, to city/regional scale habitat corridors. Collectively, these strategies can increase the capacity of the city to support endemic species, simultaneously enhancing a bioregional "sense of place", and numerous associated ecosystem services to increase urban resilience in the face of climate change.

**Keywords:** urban planning; urban regeneration; biodiversity; regenerative urbanism; transdisciplinary; urban ecology; charismatic species



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## 1. Introduction

There has long been a tension between the two notions of a sustainable city, namely the ecological city and the resource-efficient city. The resource-efficient city (e.g., net-zero/circular city) typically relies upon a compact urban form where resources are closely monitored and managed to optimise resource use with the goal of minimising negative environmental impacts [1–3]. The resource-efficient city concept benefits from a circular urban metabolism so that nutrients, stormwater and other wastes are reused as input

streams for other urban systems, thereby reducing the demand for virgin resources and thus reducing a city's global ecological footprint [4–6], whereas the ecological city aims to maximise access to nature and integration of natural systems [7].

Increasing density through urban intensification can benefit resource efficiency and increase cultural vitality, but unfortunately this is typically at the expense of urban nature and ecosystem service capacity [8]. However, new planning, design and technological approaches are beginning to demonstrate how this limitation can be overcome and ecosystem services can be accommodated within compact resource-efficient cities [9], for example, by integrating nature-positive solutions at the neighbourhood scale through ecologically led site planning. Even within the most populous and dense cities, thoughtful design can find ways to integrate nature into urban areas using techniques such as green roofs, green walls and micro-gardens at the individual plot level [7].

This paper describes possible urban planning approaches that could significantly increase urban nature while simultaneously densifying to improve resource efficiency. This follows the idea of regenerative development, for example, climate positive development which means an urban project goes beyond reduced impact to be actually repairing the atmosphere through consuming more CO<sub>2</sub> than it produces [10–12]. The paper explores how community appeal for charismatic iconic species could be harnessed to drive action for ecological repair. It describes how nature-positive urban design and development can provide measurable increases in biodiversity. We then report on several precinct scale projects in Perth, Western Australia (WA), that examine how planning and design have been used to improve and repair urban habitat of the Black Cockatoo—a “charismatic species” in the local area—as a way to regenerate local and regional biodiversity. Finally, the paper discusses how such nature-positive approaches can be systematically scaled through urban planning in future developments in Perth and other similar cities.

### 1.1. Nature-Positive Design and Development

The fundamental idea of nature-positive design and development is to not just utilise the ecosystem services that are part of any urban development but to restore the nature damaged throughout the development supply chain [13]. To do this requires compensation over and above pre-development levels. Urban nature is frequently cited as valuable for the important ecosystem services it performs, i.e., “the benefits *human populations* derive from ecosystems” [14], (p. 293, emphasis added), but increasingly such services are seen to have intrinsic *non-human* biodiversity values [13] that also need to be given assistance. The potential for introducing ecosystem-based approaches into urban planning is gaining attention from scientists, policy makers and developers as a sustainable and cost-efficient solution to address climate resilience, health and wellbeing in urban areas [15]; but with the exception of some voluntary sustainability rating systems, they are not yet seeing the potential for regenerating biodiversity habitat as an associated goal. Kirk et al. [16] observed that biodiversity is often an afterthought in urban planning, but note that considering biodiversity targets at the outset of an urban project can encourage successful outcomes for nature, improve aesthetics and liveability, and engage stakeholders in other aspects of urban design. Urban ecosystems might include parks, street trees, water courses and the services they perform include microclimate regulation, air filtration, nutrient absorption, flow management of rainwater drainage; ideally these natural elements are integrated into landscapes, buildings and infrastructure. Most of these “services” could alternatively be performed by “hard” infrastructure and engineering—but usually at far greater cost and effort—while preventing the nature-positive outcomes that can be created from green infrastructure. In addition, “cultural ecosystem services”, e.g., recreational space, aesthetic values, heritage, sense of place [17], provide complementary co-benefits that improve liveability and health for urban citizens and these “services” are also enhanced by ecologically appropriate nature-positive outcomes.

As urban areas are increasingly exposed to climate-related risks such as extreme heat and urban flooding, the role of ecosystem-based adaptation for climate change re-

silience is growing in popularity due to its cost-efficient, comprehensive, and *multifunctional* approach [18]. These services are certainly a part of green development and may have biodiversity and other advantages but are designed mostly to be beneficial to urban citizens and thus they tend to be evaluated based upon impacts on people. The plant and species selection of urban ecosystem adaptation approaches are rarely tailored to the local ecology, rather they are more likely to be selected based upon other management factors such as availability, leaf drop, tree form, climate suitability. However, with the growing recognition of the benefits of ecosystem services to create climate resilience and other liveability benefits such as cultural ecosystem services in urban areas [17], the opportunity for nature-positive design and development could be added to this process so creating the further multifunctional benefit of regenerating local ecology and biodiversity in the host bioregion. These various eco-system functions are particularly important in vulnerable and fragmented landscapes such as Perth's Swan Coastal Plain.

### 1.2. Planning Policy

To realise the multiple benefits of nature-positive design and development in urban areas requires planning policy support and regulatory guidance. The challenge is to establish processes that support multifunctional uses in spatially efficient ways; it is difficult to accommodate population growth, housing, industry, recreational uses as well as urban nature, but that is increasingly a necessity. As the growing impact of global climate change bears down upon cities, the importance of ecosystem services and nature-positive design is likely to grow as a part of planning policy [9,14,18].

There are other planning rationales for nature-positive design. Urban nature is linked to improved health, including recent evidence from Europe related to reduced mortality rates from COVID-19 where urban residents had access to green space [19]. The value of urban nature to support human needs is commonly described in terms of ecosystem services, or cultural ecosystems services with the retention and regeneration of local ecosystems less commonly discussed or valued, yet such an approach is important to preserving local species while also reinforcing the local sense of place [15,17]. Access to urban nature in cities also supports ecological literacy and advances nature stewardship within urban populations [20]. Indeed, it has been commented that, in Australia as elsewhere, it is paramount to empower communities to innovate with nature if progress toward nature-positive cities is to be made [21].

Birkeland [13] suggests that while the notion of increasing natural capacity seems counter-intuitive to the notion of development, it is possible to increase "ecological space" through carefully designed "nature-positive" structures and spaces. This is particularly true in urban areas where the ecological systems are already highly degraded [22]. Birkeland [13] suggests, that to be truly nature-positive, a development needs to design-in nature in excess of a pre-urban ecological baseline. Planning policy for nature-positive urban development could therefore create the conditions to encourage development that leaves the environment better off than if the development had not happened [23]. This is ambitious, but theoretically possible and increasingly desirable. Innovative urban planning policies in some cities are now shifting to view the city as an ecosystem [6,24], and in a few modern cities such as Singapore, developers are given planning incentives to integrate as much urban nature into new developments as possible [25,26]. Limitations imposed by buildings and roads can be overcome by verge gardens and street trees, as well as biophilic elements on and in buildings, collectively these elements contribute to a net ecological gain. In Singapore, much of the species diversity is not native (such as the rain trees that are ideal street trees in tropical cities due to their root systems and canopy cover potential), thus enabling functional ecosystems that are now attracting biodiversity gains [26,27]. The following case study describes a recently built community that included nature-positive landscaping as a central component of the development and then takes the principles into a broader discussion of how functional approaches to urban ecosystems can improve biodiversity.

### 1.3. Nature-Positive Landscaping for Endangered Species: A Case Study

Nature-positive design has been embraced as a central principle in the *Living Building Challenge* (LBC) performance standard. LBC is a highly aspirational, voluntary planning standard that encourages “regenerative design”. It covers a range of performance criteria e.g., energy, water, place, and includes how development can focus on biodiversity and ecosystem health. The ecology of place criteria suggests: “All projects must demonstrate that they contribute positively to the ecology of their place and restore or enhance the ecological performance of the site towards a healthy ecological baseline. On-site landscape must be designed to mature and evolve and emulate the functionality of the reference habitat”, i.e., to support an ecologically appropriate landscape based upon the pre-development bioregion, providing the critical dozens of ecosystem services that help a place to thrive. This does not mean purely local species are used as already there are clear signs of some new species that can assist with the regeneration of the urban ecosystem’s functionality. The standard also requires that land is set aside in high conservation areas to off-set the land taken up by the building. This is not yet positive development, where additional nature is created through designing nature into and onto buildings, but it is acknowledging the space taken up by buildings.

The following case study from Castlemaine, Victoria, describes an integrated planning process whereby a degraded greenfield site was redesigned and regenerated using LBC principles with a strong landscape plan focussing on food production and ecosystem repair with an emphasis on some iconic biodiversity.

Castlemaine is a town of 10,000 people, 129 km north-west of Melbourne, 280 m above sea level, with between 400–800 mm of rain per year. The custodians of the country, the Dja Dja Wurrung and Taungurung Aboriginal people live in the area and have done so for many thousands of years, “they had a thriving economy based on the barter of greenstone (diorite) for axe heads, food, possum skins, wattle gums, spinifex resin, grinding stones and ochres” [28].

On the urban edge of Castlemaine, “the Paddock” was designed to be a 27-home development on 1.34 ha of degraded land previously cleared for gold mining, then used for sheep farming and chicken sheds before being bought by its current owners. As part of following a LBC framework and the leadership and passions of the landowners and the architect Geoff Crosby, the homes were designed in a horseshoe townhouse configuration leaving space for food growing and nature. Phases 1–3 have been completed with phase 4 under construction.

At the project outset an ecologist was commissioned to assess preconditions and to advise the landscape design. This involved an ecological baseline study across three seasons to determine existing conditions (soil, water, birds, mammals, vegetation). The study used citizen science in collaboration with the Latrobe University Bendigo and Melbourne University students to conduct bird counts, install sensor cameras, analyse soil samples and water samples and carry out quadrant studies, vegetation and tree assessments. The outcomes of the analysis were taken by ecologist Cristina Hernandez Santin to create a plan of what it could look like if the project restored the ecosystems. She identified the powerful owl, growling grass frog, legless lizard, golden sun moth and sugar glider as key iconic species that could return given the design and development of the site, with their charismatic appeal useful for community engagement—including community-led habitat repair and citizen science monitoring.

The project team, especially the landscape architects, took this information and the site plan and developed a strategy for tree conservation, weed elimination, water and drainage systems, landscaping and strategic planting that could support the health of the site and lead to regenerative nature-positive outcomes (see Figure 1).





**Figure 1.** Landscaping at The Paddock in Castlemaine, Australia.

On completion of phase 1, the owl, the golden sun moth and the frogs have been seen or heard. There have also been visits of other species such as an echidna. The return of these species not only supports the approach of this project but residents have also reported a sense of joy, attachment and belonging to the place, a virtuous cycle that fosters the sense of stewardship amongst residents who are proudly co-observers and active participants in maintaining the health and vitality of the site. Residents continue to actively manage weeds, plant native species, and run workshops on site for those moving into the development based on its ecological features. As part of an ongoing adaptive management process, discussions have begun with the management committee to fund the 5 and 10 year impact assessment starting in 2026. Ultimately, it would be desirable for the impact assessment to measure “nature offsets for buildings” to compensate for losses during resource extraction and manufacturing experienced beyond the site boundary, thus becoming truly nature-positive.

There are other sustainability aspects of the LBC that could be relevant to the journey that we cannot go into here, aspects such as: a Life Cycle Assessment (LCA) of building impacts which are offset; the water positive contribution through the additional flows brought to site by the residents (i.e., water harvesting and reuse within the site boundary); the energy positive design (i.e., a net excess of renewable energy) resulting in contributions both to shared areas such as the “fixing shed” and car charging, but also back into the community or exported to the electricity grid; and the celebration of the history of the site through community-curated paths and the intentional governance framework developed by the community for decision making.

The Castlemaine case study was driven by commitment to a voluntary rating system; in this sense, the leadership for the commitment to regenerative outcomes came from the development group. The demonstration of regenerative principles at Castlemaine is on-going, but is encouraging so far, however, while voluntary approaches are important for proof of concept there is a need for more ambitious planning controls to scale regenerative development outcomes. For every voluntary regenerative development, a far greater number of conventional unsustainable developments are built that cancel out any sustainability gains from the few exemplary projects. The question of whether regenerative development approaches can be mainstreamed into urban development remains.

## 2. Methods

This paper describes an action research approach to urban planning. The action research framework for inquiry seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people [29]. The pressing concern being considered in this paper is whether urban nature can be regenerated as part of urban development and the specific research question—could urban planning instruments be utilised to systematically increase nature-positive outcomes as part of the development process in Perth and other similar cities? In keeping with historic action research approaches, the research design involves collaborative, comparative research to influence social action, but to reduce adverse risk of positionality or bias from prior experience and beliefs, a multiauthor team was assembled representing several disciplinary backgrounds; together, the authors effectively represent a transdisciplinary team, including expertise in ecology, academia, property development and urban planning. Disciplinary divides can result in siloed thinking, but transdisciplinary collaboration can generate new knowledge [30]. In this case, we hoped to create a nature-positive design and development framework that could integrate areas that are typically treated as separate, non-intersecting realms. However, to be effective such a framework must be:

- Grounded in ecological evidence to ensure empirically valid nature-positive improvement;
- Framed in viable planning outcomes with measurable performance indicators in terms of liveability outcomes for residents and the local community as well as for biodiversity and other nature-positive outcomes; and
- Financially viable so that there is a business case which will enable investment and ensure implementation that has a marketable demand.

Collectively, these three professional lenses need to integrate the ecological, social and financial aspects of regenerative design through the planning process.

The study was limited to the city of Perth in Western Australia. An assumption made at the outset of the research was to focus on the popularity of one keystone species, the iconic Black Cockatoo, as a leverage point for greater public sympathy to increase urban nature and biodiversity and hence make nature-positive urban planning more palatable. Starting from this premise we reviewed several known precincts in Perth that have incorporated Black Cockatoo habitat into their design with a view to gleaning replicable lessons capable of being scaled up as urban planning recommendations.

The goal was to develop a framework for Perth as an example of local action to support global goals for (urban) biodiversity restoration, e.g., alignment to recommendation 8 from the combined IPBES and IPCC Biodiversity and Climate Change report that calls for “*A new conservation paradigm would address the simultaneous objectives of a habitable climate, self-sustaining biodiversity, and a good quality of life for all. New approaches would include both innovation, as well as the adaptation and upscaling of existing approaches*” [31].

The following sections provide: examples of iconic species catalysing nature-positive action; an introduction to Perth and its bioregion; an introduction to the Black Cockatoos and their habitat needs; and recent urban precinct case studies that incorporate cockatoo friendly landscape elements. The final section considers all this material and presents a nature-positive design and development framework based around a range of cockatoo friendly urban design principles.

### 3. Study Area and Data

#### 3.1. Charismatic or Iconic Species

The “charismatic” appeal of iconic species such as those used in “the Paddock” development can help win the hearts and minds of the public; in this sense, the appeal of charismatic species functions as a “deep leverage point” by tapping into pre-existing values to drive sustainability [32]. The use of charismatic species to promote conservation has a long history. Sixty years ago, in 1961, the World Wildlife Fund (WWF) latched onto the charismatic appeal of the endangered panda which they used in their logo as a visual and emotive device for communicating their conservation message. Initial sketches by the British environmentalist and artist Gerald Watterson and Sir Peter Scott, one of WWF’s founders and a world-renowned conservationist and painter, resulted in the development of the highly recognisable symbol that would overcome language barriers [33]. However, perhaps more important is the emotional connection charismatic species such as the panda evoke, that is capable of eliciting action for conservation.

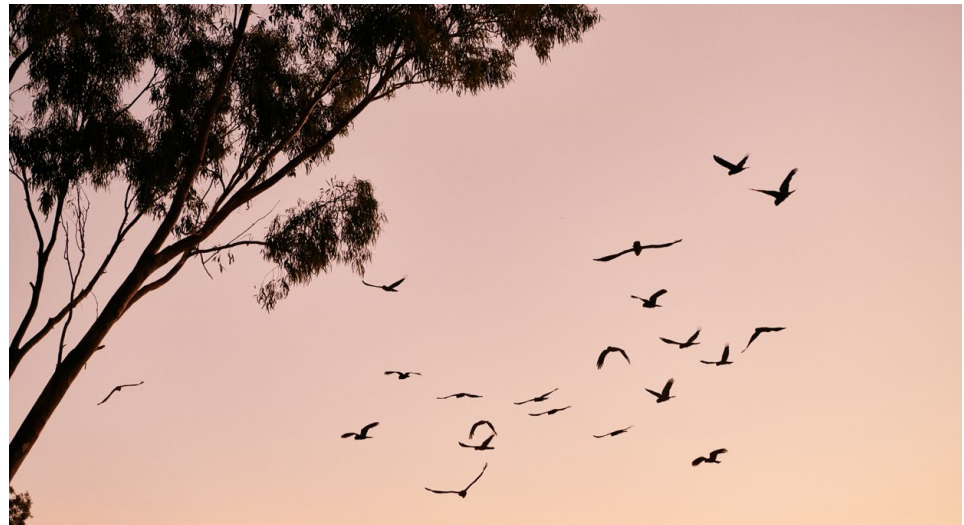
In addition to the localised use of iconic species in projects such as “the Paddock”, in Australia—the koala—another charismatic species has catalysed a national community conservation movement (see Box 1).

#### Box 1. Koalas as iconic species.

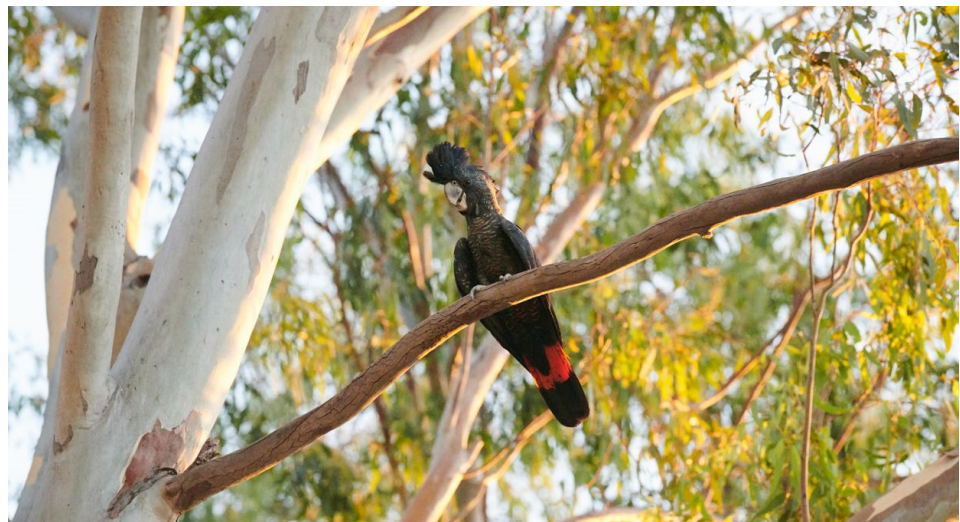
Koalas are found in the forests of South Eastern Australia. Since 2006 the not-for-profit Australian Koala Foundation (AKF) has been monitoring and mapping all known wild populations of koalas and koala habitat. In 2012, the Australian government listed koalas as vulnerable to extinction due to observations of declining populations. Over the three years from 2018 and 2021, the national koala populations declined around 30% as a result of sustained environmental pressure related to continuing habitat clearance compounded by massive bushfires [34]. In response to the tragic decline of this species and the high profile it has within the community, a Koala Act has been proposed (but not enacted) as an attempt to legislate the protection of koalas and their habitat both within nature reserves and within urban areas containing their habitat. According to the AKF, the intent is not anti-development, but rather to protect koalas and their habitat. AKF cite an example of nature-positive design and development as the Koala Beach resort. The resort was a collaboration between developers and the AKF, on the site of an old cattle grazing property in northern NSW. From 365 hectares of developer-owned land, 272 hectares were dedicated to ecological conservation, and 500 homes and supporting infrastructure were located on the remaining 92-hectare-development footprint within previously cleared and disturbed habitat. The development was based upon “koala friendly urban design” structured around the *Koala Beach Principles* [34]:

- No cats and dogs within the estate;
- The inclusion of speed bumps near known Koala home ranges;
- A requirement that all fences within the estate be removed so that Koalas and other wildlife can enjoy free access around the estate;
- The provision that no Koala home range or food tree be removed for development purposes;
- The establishment of a Wildlife and Habitat Management Committee with funding from an environment levy on the rates.

Our case study considers Perth in the Swan Coastal Plan (SCP). The SPC is not home to koalas, but it is home to the much loved, and highly visible, Black Cockatoo species. Just as the charismatic appeal of koalas helped build momentum for new forms of development and drive policy debate around habitat protection within its bioregion, we believe a similar approach may work using the popularity of the Black Cockatoo to protect and potentially expand its habitat in Perth. The Black Cockatoos, although relatively few in number, are highly conspicuous throughout the city as they fly slowly and majestically in flocks (Figure 2) between habitat patches with their piercing call audible for kilometres. The large, beautiful and charismatic birds (Figure 3) attract attention wherever they congregate. They have earned the right to be called an iconic species in Perth.



**Figure 2.** Cockatoo flock (photo: Rebecca Mansell).



**Figure 3.** The iconic Red-Tailed Black Cockatoo (photo: Rebecca Mansell).

Black Cockatoos enjoy passionate support from Perth's citizens; therefore, this paper attempts to outline urban planning measures that could support "cockatoo friendly urban design" and development as part of a nature-positive design and development. Approaches are outlined that show how recent and proposed urban development can enable an ecosystem-based, climate adaptative and regenerative habitat that can demonstrate, in a Perth context, the meaning of nature-positive urban development.



### 3.2. Background to Perth and the Swan Coastal Plain

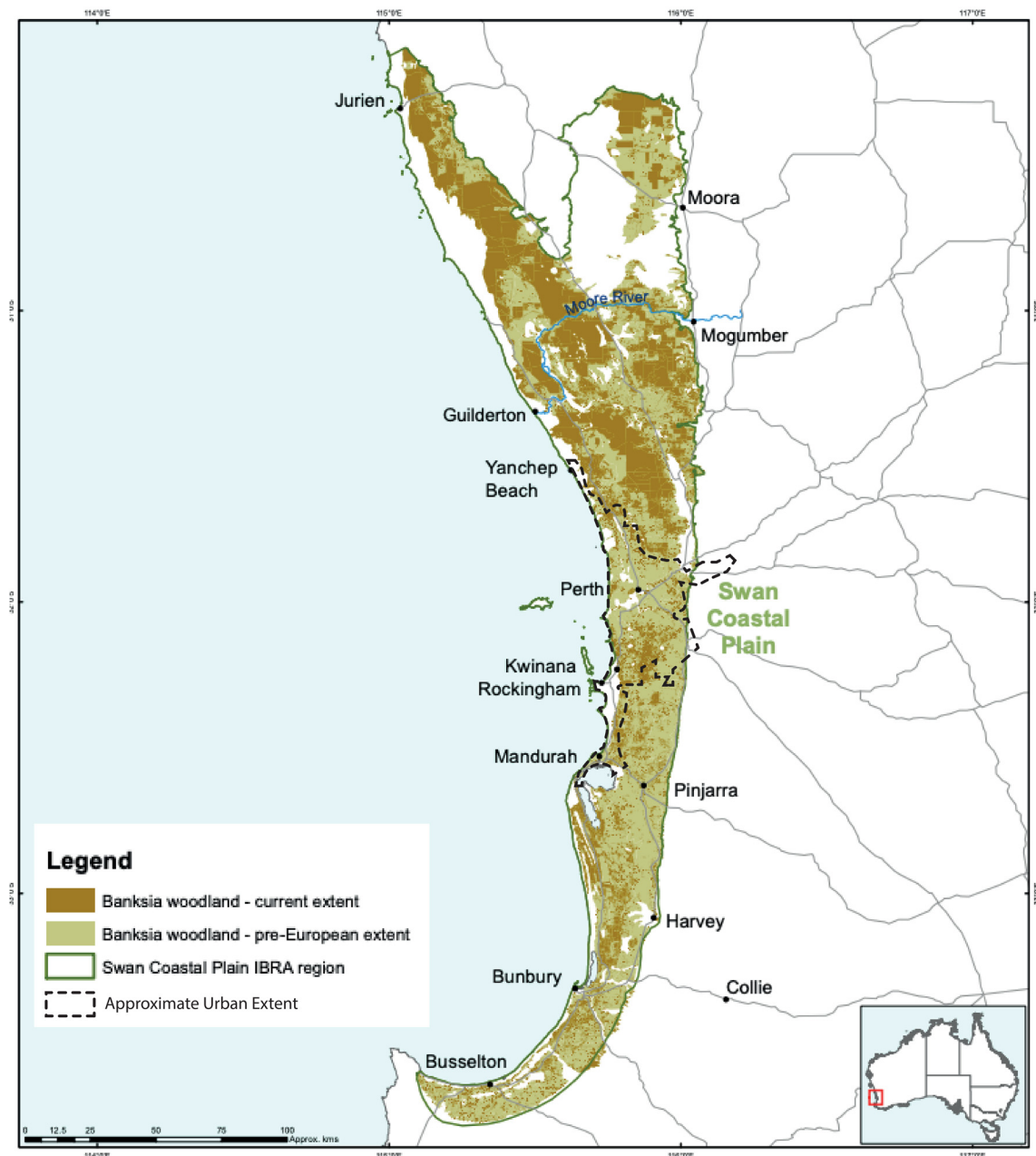
Perth today is a low-density sprawling city of over 2.1 million people centred around the Swan River—the Black Swan (*Cygnus atratus*) after which the river is named, is another iconic local bird species. The Swan River Colony on the SCP began in 1829 as a British colonial outpost. The early colonial enterprises involved clearing large areas of the expansive forests and making way for productive agricultural land to support the new colony. These practices have largely continued as subsequent generations of predominantly European settlers have sought to exploit the land for economic reasons such as logging, farming, mining and urban development. In each instance, the natural landscape is largely removed to accommodate a change in land use, often with little regard to the pre-existing ecological community, though attempts in the 19th century such as Kings Park were made to ensure native vegetation remained [35].

Reflecting a broad cultural preference within Australia to live near the beach, most of Perth's urban development can be found upon the SCP fringing the Indian Ocean. The result is a notable north-south orientation to the city's footprint that stretches over 150 kilometres from top to bottom. This coastal urban growth axis is an ongoing trend that means the city is effectively superimposed upon the SCP—the narrow landscape sandwiched between the Indian Ocean and the Darling Scarp. The SPC, despite comprising relatively infertile sandy soil, supports a very rich habitat of unique flora and fauna. The southwest of Western Australia has been ecologically isolated for millennia; this isolation has resulted in the evolution of many endemic species. Human activity from the colonial era, both agricultural and urban development, has displaced much of the pre-colonial landscape and the SPC and all of the southwest of Western Australia is now a severely fragmented landscape (see Figure 4)—the entire region has been identified as a “biodiversity hotspot”, i.e., a location where exceptional concentrations of endemic species are undergoing exceptional loss of habitat [36].

Perth is expected to grow considerably in size from its current population of 2.1 million in 2021, to 3.5 million by 2050 (pre-COVID projections). In recognition of this planned growth, the Western Australian Planning Commission released a strategic plan—*The Plan for Perth and Peel at 3.5 Million* [37] arguing the benefits of consolidating the present urban fabric. The plan states that there is sufficient land for future greenfield development, but the city needs to achieve infill rates at 47% to 2050. Conventional urban growth is a driver of climate risks as increasing urban intensification tends to subsume the natural and the climate adaptation benefits (ecosystems services) offered by urban nature. Both urban expansion and urban infill in the past have had a destructive impact upon remnant stands of ecologically valuable land in urban, peri-urban and fringe land. Peri-urban and fringe subdivisions can be expected to destroy remnant ecological communities, while most infill development in Perth tends to involve the demolition of older houses on large blocks (e.g., 800–1000 m<sup>2</sup>) and replacement with 3–4 dwellings and in the process the removal of mature trees. This can mean the reduction of cockatoo habitat, as well as dissociating residents from local nature. New approaches to infill are being discussed [38] and design guidelines created [39] which are now suggesting how to include nature into dense urbanism in Perth.

The Noongar people, as the traditional custodians of the southwestern region of WA, have a deep understanding and connection to the land acquired over 60,000 years of continuous occupancy; this knowledge has not widely permeated the most populous, recently arrived, settler population. A lack of ecological understanding is reflected in the imported British knowledge, laws and practices that underpin planning controls. Indeed, previous studies into the ecological literacy of residents in southwestern WA, even where they express concern for the environment, revealed very low levels of ecological literacy [40]; a notable exception was an awareness of “charismatic species” (e.g., in the Stocker et al. study possums, quenda and peppermint trees were mentioned by respondents). Stocker et al., ([40], p. 146) conclude that “the results indicate many participants were anthropocentric, prioritising their own livelihoods and lifestyles with ecological systems being important only in so far as they support these proximal human needs”. In

some ways, the anthropocentric nature of the participants in this research study can be seen as having some sort of equivalence to the anthropocentric notion of ecosystem services. However, the opportunity is there to use new kinds of nature-positive urban design and development that can educate residents and the whole planning culture that biodiversity can be regenerated in cities. Sustainability education and training within an institution can bring about relatively rapid organisational culture and policy shifts towards sustainability [41]. This is particularly true for land use planning which is effectively the DNA of a city, dictating its ultimate form. If nature-positive requirements can be embedded into planning codes then urban habitat would effectively increase as part of each new development.



**Figure 4.** Banksia woodlands of the Swan Coastal Plain, and urban extent of Perth. Modified from source: Australian Government Department of Environment, 2016.

### 3.3. The Black Cockatoo

Three species of Black Cockatoo are endemic to the southwestern region of Western Australia [42]. Two species are called “white tailed”, i.e., Baudin’s Cockatoo (*Calyptrorhynchus baudinii*) and the Carnaby’s Cockatoo (*Calyptrorhynchus latirostris*); the third is the Forest Red-tailed Cockatoo (*Calyptrorhynchus banksii naso*) [43]. Collectively, Black Cockatoos represent a very distinctive part of the avifauna in the southwest of WA, all have experienced range retractions and substantial declines in populations over the last 50 years [44]. All three species are threatened, with the Australian Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* listing the Carnaby’s cockatoo and Baudin’s cockatoo as “endangered” and the Forest Red-Tailed Cockatoo as “vulnerable” [45].

Figure 4 shows the Interim Biogeographic Regionalisation for Australia (IBRA) designation for the SPC and the extent of former and remnant Banksia Woodland. The Banksia Woodland ecosystem is listed as a Threatened Ecological Community (TEC) by the Australian Government [46]. This TEC represents a critical habitat for the Black Cockatoos, the dashed line shows the extent of Perth’s urban development and the high proportion of overlap. The main loss of Black Cockatoo habitat is from rural clearing, though not much is left inside the urban fabric either and introduced plantation pine species from the 1930s which assisted their retention, are now being cleared for urban development. The loss of foraging habitat, the lack of suitable breeding sites, climate change, alterations in the landscape, changing forest structure and the impact of introduced and invasive species (especially feral European honey bees), corellas and galahs has had an impact on all three species of Black Cockatoo in the SPC [47,48]. Perth remains fortunate to have an endangered species in its suburbs; however, significant declines in all three Black Cockatoo species have been observed since the 1980s [48] and there is some urgency to develop management plans for the future [47–49] which will need to include urban design and development.

All three Black Cockatoo species are at risk due to low reproduction rates and habitat loss, but the cockatoo is just one species of many in this ecological assemblage at risk. The goal of this paper is to show how it may be possible to tap into the iconic appeal of the Black Cockatoo to promote a “nature-positive” design and development approach. Such an approach would support habitat regeneration for the cockatoos and other species with a goal for a net increase in cockatoo-relevant vegetation over and above pre-colonial habitat within present and proposed urban boundaries.

To understand the types of recommendations required to be implemented within planning, it is necessary to understand cockatoo habitat needs, this must be ecology-led, key points are summarised in Box 2.

**Box 2.** Characteristics of cockatoo habitat.

Extensive cockatoo habitats have been measured through bird tracking [48,49]. These studies revealed that cockatoo movement patterns are highly dependent upon habitat, both roosting and foraging species. Cockatoos also have a home range—also dictated by habitat species and quality. Shepherd and Warren’s [49] field observations report that cockatoos congregate around:

- **Forage and roosting habitats** centred around tall tree species dominated by marri (*Corymbia calophylla*) as well as jarrah (*Eucalyptus marginata*). Trees were mature and ranged in height from 10–20 m. Foraging species also include lemon scented gum (*Corymbia citriodora*), blackbutt (*Eucalyptus patens*), illyarrie (*Eucalyptus erythrocorys*) and she-oak (*Casuarina* spp.), along with various non-natives including tipuana (*Tipuana tipu*), liquid amber (*Liquidambar* spp.) and jacaranda (*Jacaranda* spp.). In recent times, there has been a dynamic change in the foraging ecology of Forest Red Tailed Black Cockatoo on the SPC (see: [50]) with the discovery of, and exploitation of, Cape Lilac, a species from outside the local bioregion that is now common in Perth landscaping.
- **Access to water**, with day roosts located near water bodies or artificial water sources, e.g., water trough (around 2/3 of sites in the 2019 field survey), but water sources did not seem so critical for night roosts.
- **Canopy cover** on roosting sites ranged from 17–59%.
- **Nesting sites** in large tree hollows, especially the oldest trees, e.g., Marri 200+ years (N.B. very few survive, and those remnant trees are suffering a high rate of loss, c. 16.6% per decade) [47].

Tracking is not a good indicator of foraging habitat except in pine plantations, but ground truthing is, i.e., looking for evidence of feeding (both old and recent evidence) to determine a change in status of birds during different times of the year and from year to year [45]. For example, transect maps for Forest Red-tailed Black Cockatoos foraging on the southern SPC showed very different habitat use in 2015–2016 compared to 2017–2018 due to the nutting cycle of Marri. Furthermore, there was a decrease in numbers of both Carnaby’s and Baudin’s cockatoos on the southern part of the SPC in 2018 compared to the previous year following the tree cycle in the area.

Studies by the Western Australian museum found the right size and dimension of artificial PVC nests that were suitable for Black Cockatoos but unsuitable for feral bees and invasive native competitor species, e.g., Galahs and Corellas; these have proven to be very successful and thus provide a very useful and encouraging sign that a nature-positive urban development can be possible [44,47].

Cockatoo habitat is at risk from clearing, loss of mature trees due to urban infill, and car strike along roads. A key measure for the re-establishment of cockatoo habitats on the SCP is to plant more habitat and roosting trees. In addition, to support the slow breeding cockatoos, more nesting sites, most likely artificial cockatoo nests, are needed to make up for losses in natural nesting sites. Having food resources that support Carnaby’s Cockatoos (even for short periods) during their migration is essential for their long-term survival on the SPC. This functionality needs to be built into the landscape design of the Perth urban area.

**4. Perth Case Studies That Design in Cockatoo Habitat**

There are several precedents in Perth that have already demonstrated how Black Cockatoo habitat can be inserted into Perth’s urban land use. Each represents a large precinct-scale development within the Perth metropolitan area with a single organisation leading and implementing the change. Two are universities (Curtin University, Murdoch University) and one is an industrial estate (Roe Industrial estate, owned and managed by Hesperia). In all three examples development was proposed on, or adjacent to, land known to support existing Black Cockatoo populations. Each organisation conducted ecological surveys to help determine how habitat could not only be preserved, but also be regenerated.

Pine plantations around the metropolitan fringe at Somerville plantation (later Murdoch University), as well as Collier plantation (later Curtin University) were used by thousands of Carnaby’s Cockatoos in the 1930s and onwards until the plantations were removed for urban development. This policy of creating a cash flow from urban deferred land owned by the government had the side effect of creating a large habitat for Carnaby’s Cockatoos. So the last remaining flock in the western suburbs of Perth forage on remnants of pines, native bushland and gardens, and at the sites below, attempts are being made to enable nature-positive urban development that assists these iconic birds to thrive.



#### 4.1. Curtin University

At Curtin University, preliminary work was conducted into cockatoo habitat prior to the development of a 2014 masterplan to support the university expansion. Prior to becoming an education campus, the site was a Maritime pine (*Pinus pinaster*) plantation, dating from the 1930s. Cockatoos are amenable to the exotic pines, which provide an important habitat for food and roosting; however, many of the mature pine trees, are nearing the end of their lifespan; despite not being native, the loss of pines poses a further threat to the Black Cockatoo.

To improve the food source for the Black Cockatoo, Curtin University has a planting program across the 116 hectare campus incorporating a variety of mature tree and tube stock of high priority feeding trees, including Tuart (*Eucalyptus gomphocephala*), Marri (*Corymbia calophylla*), Banksia (*Banksia grandis* and *Banksia menzies*), Willow myrtle (*Agonis flexuosa*) and red-flowering gum (*Corymbia ficifolia*). Degraded wetlands on the campus are also being revegetated with large trees, including the flooded gum (*Eucalyptus rudis*), Banksia (*Banksia littoralis*), macadamia and almond, to provide additional food sources for the Black Cockatoo as part of an ongoing habitat restoration program in parallel to building construction works [43].

#### 4.2. Murdoch University

Murdoch University has similar habitat protection and regeneration initiatives across the 227 hectare campus. In addition, university ecology and ornithology researchers have been monitoring cockatoo habits well beyond the campus boundary, e.g., using GPS and ARGOS PTT tags to track wild Black Cockatoos across their entire range throughout the Perth metropolitan area and southwest region [48]. The movement data captured in this research helps government agencies to better understand the ecology of Black Cockatoos, and identify critical feeding, roosting and breeding habitats [48]. This data also is useful for proponents in guiding development planning on the SPC and to assist State and Federal agencies in assessing development applications with a view to maintaining, enhancing and increasing cockatoo habitat, including in the Roe Highway Logistics Park (ROE) discussed next.

#### 4.3. Industrial Precinct Case Study

Cockatoo tracking provided evidence to support developers in understanding the habits and range of a transitory population of cockatoos discovered during planning for a new industrial park known as the Roe Highway Logistics Park (ROE). Thirty rural residential sites adjoining existing industrial land were acquired for the development of an “eco-industrial park” with a focus on low carbon and other resource efficiencies. Early in the project planning, the Roe site was identified as a roosting site for the endangered Forest Red-Tailed Black Cockatoo; despite official counts indicating that no Black Cockatoos were present in 2015, the figures rose to 334 in April 2018 and sparked the involvement of numerous interest groups. This activity led to the developer immediately sectioning off the roost, working with community interest groups, the Western Australian Museum, Murdoch University, Local and state government and relevant agencies to finalise the Roe Conservation Strategy. The award-winning strategy involved:

Habitat regeneration, including:

- A planting day with 2000 Marri seedlings planted by community interest groups and developer staff;
- Funding of labour and materials to the local government to plant 60 Marri trees in the nearby Woodlupine Brook Reserve;
- Planting the Tom Bateman Reserve (19 September), using 300 Marri trees donated to the local government;
- Planting at Roe (20 January), using 322 mature trees and 1688 tree tubes within the park.

Research and monitoring funding, including:

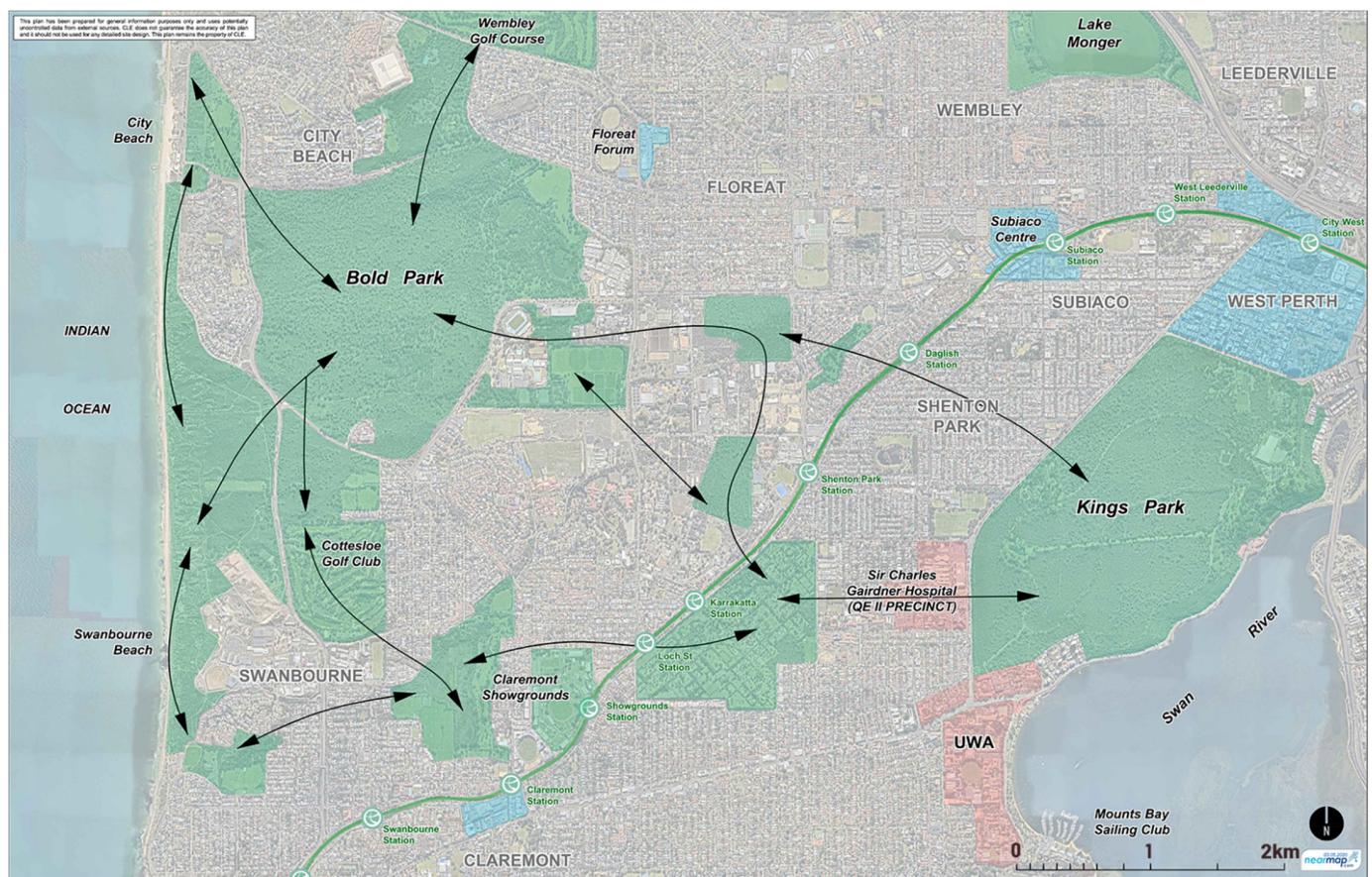
- A research grant to Murdoch University to gain insights into Forest Red-Tailed Black Cockatoo movement across the SPC;
- Research funding to support the Western Australian Museum map and monitor the roosting site;
- Ongoing environmental monitoring measures to ensure the success of the strategy.

The completed research provided important industry knowledge of flock movements and the practical measures developers can take to integrate environmental habitat into their project. The collaboration between developer, municipality and ecologists was supported by the business activity of redevelopment this allowed research to be conducted that may not have happened otherwise.

Each of the three case studies above benefited from being a large land parcel, containing remnant habitat, and managed by a single organisation. This is not typical of development areas across Perth, but it does show that nature-positive design and development can occur. The approaches tested on each site could present a range of strategies and lessons that can be gleaned for use by local governments, state agencies or developers in the Perth region, to inform design guidance across a range of development scales, as “cockatoo friendly urban design principles” that can help systematise nature-positive design and development for the Perth and Peel area of the SPC.

Despite large swathes of the original SCP’s native vegetation having been replaced by urban development, significant patches do remain. Cockatoo tracking conducted across Perth [48,49] has identified existing flight paths, roosting and foraging areas. Field surveys are used to “ground truth” to identify potential habitat or sites for regeneration to enhance remnant habitat, strengthen habitat quality and increase overall biodiversity and ecosystem services. Figure 5 shows major remnant habitat in the demographic heart of Perth, indicative flight paths between these habitat patches are shown by black arrows.

Many, but not all, of these remnant patches are protected reservations. A potential mechanism for those that lack current protection are “green trusts”—ongoing perpetual funds for financial support, possibly sourced from adjacent development or land taxes, to allow ongoing maintenance and monitoring of major habitat fragments. Such green trusts need to build on the social capital already present in the community due to local activists with interests and understanding of the local ecology. Such groups have been a significant part of the cockatoo-habitat regeneration outlined in the three case studies above.



**Figure 5.** Remnant bushland patches and cockatoo habitat in the inner Perth metropolitan area, arrows indicated observed cockatoo flight paths (source: CLE Town Planning + Design).

## 5. Results of Nature-Positive Design and Development Case Study Observations

The co-authors have drawn upon their expertise from both within and outside the field of urban planning, e.g., ecology, development and academia, and by considering the evidence observed from the three existing “cockatoo friendly” Perth case studies as well as another urban development that is being planned on the SCP, to develop a framework comprising a set of principles for scaling cockatoo friendly urban design and development—see Tables 1–3. The principles describe ecological and urban planning (design and development) measures to systematically drive the uptake of nature-positive design and development that preserves, regenerates and expands cockatoo habitat and urban biodiversity within the SCP; provides ecosystem services, and fosters ecological stewardship within urban communities.

Because ecological systems form a fluid continuum and do not adhere to political or legal boundaries, the nature-positive “cockatoo friendly” urban design principles suggest a range of approaches that need to be addressed across several scales including:

- **Regional/city scale** planning responses (Table 1), involving long term strategies and targets and metropolitan (and beyond) governance co-ordination. Regional scale solutions are important to ensure large scale systemic change and significant positive environmental impacts;
- **Precinct scale** (similar to the Perth case studies above) planning responses (Table 2) that can be co-ordinated across a large site, or a collection of adjacent land holdings at the local level. Previous studies show the importance of precinct scale planning as the larger site area offers greater opportunities for nuanced site design [51,52], e.g., potentially allowing the preservation of valuable habitat, and compensating with a higher floor area yield in less sensitive areas; and



- **Individual garden and building scale** planning responses (Table 3) to guide the piecemeal development choices that occur on individual lots that make up the majority of any city’s urban fabric. Adoption of these principles could be through municipal planning policy or individual site developer choice.

**Table 1.** Regional/city scale cockatoo friendly urban design principles.

Regional/City Scale—“Cockatoo Friendly” Urban Design Principles
<p><b>ECOLOGY MEASURES</b></p> <ul style="list-style-type: none"> <li>• Understand the functionality of the original ecosystem that supported the cockatoo populations and how these can be replicated in an urban environment.</li> <li>• Map and legislate for protection and regeneration of known cockatoo habitat—including habitat improvement by balancing roosting, nesting, foraging and watering qualities.</li> <li>• Map and identify potential regeneration sites and work with land owners and interested parties to develop an integrated network of (remnant and newly planted) bushland patches and corridors as part of an ecology-led metropolitan cockatoo habitat restoration program, see Figure 5.</li> <li>• Provide educational support through ecologists regarding preferred fauna species for preservation and planting, e.g., see Box 2. Evidence suggests Cockatoo (Forest Black) have a “home range” from 8–45 km<sup>2</sup>, therefore foraging species should be clustered within proximity (0.5–5 km) of home roosts [49].</li> </ul>
<p><b>PLANNING MEASURES</b></p> <ul style="list-style-type: none"> <li>• Collaborate and co-ordinate urban planning with existing ecological and ornithology networks to support ecology-led strategic planning efforts, including: <ul style="list-style-type: none"> <li>○ government agencies responsible for conservation efforts,</li> <li>○ formal institutional research networks such as universities, zoos, museums;</li> <li>○ relevant voluntary and charitable interest groups;</li> <li>○ citizen science groups to “crowdsource” monitoring of habitat and cockatoo populations.</li> </ul> </li> <li>• Work with authorities to identify potential land and processes suitable for “Green Trusts” to safeguard, manage and maintain critical cockatoo habitat</li> </ul>

The approaches set out in Tables 1–3 are a form of urban transition management adhering closely to the governance levels described by Wittmayer and Loorbach [53]:

- *Strategic level activities* to support long term goals, i.e., the vision for nature-positive design and development within the Swan Coastal Plan;
- *Tactical level activities*, i.e., targeting changes in established structures, institutions and regulations; and,
- *Operational level activities*, i.e., short-term experiments and actions to trial and showcase ideas.

The strategic and tactical level activities outlined in Table 1 aim to provide a bridge between science and planning with the goal to increase cockatoo habitat within urban areas. The principles could be used by a range of professionals to affect change, e.g., developers through current and future projects, ecologists as advisors to developers and planners through the regulatory system, and academics by educating future urban designers and planners.



**Table 2.** Precinct scale cockatoo friendly urban design principles.

<b>Precinct Scale—“Cockatoo Friendly” Urban Design Principles</b>	
<b>ECOLOGY MEASURES</b>	
<ul style="list-style-type: none"> <li>• Map the site and local context to identify the precinct’s “landscape footprint”. Identify high-quality bushland habitat to retain and preserve; identify degraded habitat that can be regenerated including breeding trees and all significant trees &gt;500 mm diameter.</li> <li>• Identify vegetation regeneration opportunities to link habitat patches to form landscape corridors.</li> <li>• Retain, preserve, and connect corridors through a landscape-led site design that responds to the local site conditions and wider ecological links.</li> <li>• Revegetate and regenerate using functionally appropriate plant species, implementing extensive revegetation planting programmes within and around the development, prioritising green corridors over street corridors, and setting aspirational canopy targets that support local fauna.</li> <li>• Preserve as much remnant bushland as possible through providing real opportunities for connection with nature that reinforces any bushland character.</li> <li>• Ensure precinct-wide adoption of water-sensitive urban design through appropriate technologies for local water capture, storage, treatment and reuse, including accessible water sources for cockatoo hydration, particularly in the vicinity of foraging roosts.</li> <li>• Design roosting forests through street trees and parks.</li> </ul>	
<b>PLANNING MEASURES</b>	
<ul style="list-style-type: none"> <li>• Adopt the Black Cockatoo as an “indicator species” and monitor populations with the goal to increase foraging, roosting, breeding activity over time. Existing cockatoo and bird conservations organisations as well as citizen science programs can be recruited to conduct and verify bird counts.</li> <li>• Minimise hardscaping through small, rather than large, building footprints (up, not out, e.g., an FSR of 1:1 as a single storey is 100% site coverage, as a three-storey building 33% site coverage), narrow street widths to maximise on-site opportunities for deep rooted planting to support large trees.</li> <li>• Create “biophilic streets” that incorporate ecosystem services, and treat streets as multifunctional corridors rather than simply vehicle corridors, i.e., to accommodate water drainage and retention and to integrate vegetated verges for habitat including canopy, mid-storey and ground cover.</li> <li>• Consider the impact of a changing climate upon cockatoo habitat by including resilient habitat species in new plantings: in Perth, this would mean planning for increased incidence of extreme heat, low annual rainfall and cyclonic activity.</li> </ul>	

**Table 3.** Individual garden and building scale cockatoo friendly urban design principles.

<b>Individual Garden and Building Scale—“Cockatoo Friendly” Urban Design Principles</b>	
<b>ECOLOGICAL MEASURES</b>	
<ul style="list-style-type: none"> <li>• Set goals for each plot to be “nature-positive” with a net increase in vegetation on the site over and above pre-colonial habitat.</li> </ul>	
<b>PLANNING MEASURES</b>	
<ul style="list-style-type: none"> <li>• Provide design guidance for cockatoo friendly and nature-positive housing</li> <li>• Encourage “biophilic buildings” that incorporate vegetation, on and over and around the built form with roof gardens and green walls incorporating native species for hardiness and habitat.</li> <li>• Incorporate “deep soil zones” on every private lot and in apartment gardens to allow for endemic canopy trees (e.g., Jarrah, Marri, Tuart).</li> <li>• Introduce artificial nest hollows suitable for cockatoos.</li> <li>• Provide households with “information packs” to educate on cockatoo habitat, the local ecology, where to source native species, the benefits of nature-positive development and how to become an urban nature steward through involvement in cockatoo or bushland conservation groups.</li> </ul>	

Widespread application of these principles could increase access to nature across the city of Perth; they have the goal to support nature-positive design and development, i.e., a net increase in urban nature over and above the pre-development conditions. While it is possible to achieve nature-positive outcomes within a well-designed development, there are limitations, such as large roads or other infrastructure that displace urban nature. Currently, no city can claim to be nature-positive although the concept is theoretically possible, and as outlined above, there are growing examples of how to design nature-positive solutions into urban environments. However, these opportunities may not be taken up unless the planning system encourages them. If such principles were not voluntary, as in rating systems such as Living Building Challenge, but rather were adopted as planning policy to systematically increase urban nature, this would allow urban development to be reframed from a degenerative, to regenerative force for urban nature. The charismatic appeal of iconic species, such as the Black Cockatoo, have the potential to function as catalysts for education, and for winning widespread community support, to implement such measures. The risk of extinction for the Black Cockatoo highlights the crisis being faced in the Perth region much more saliently, for example, than the statistics of tree loss might. While planning is the mechanism that can systematically scale nature-positive actions, there is an increasingly important role for ecologists to monitor progress within the urban environment, the ecological lens is the only way to measure the effectiveness of biodiversity repair. Non-ecological co-benefits, such as ecosystem services and cultural ecosystem services are not insignificant, both benefiting from outcomes. Quantitative outcomes from nature-positive regenerative urbanism ought to become part of the planning process in order to ensure regenerative urbanism is mainstreamed and that the added value is demonstrable.

To deal with the uncertainties associated with complex adaptive socio-ecological systems (e.g., changes in climate, policy, on-the-ground observations), the proposed principles would benefit from adaptive management approaches, where goals and actions are adapted to ongoing changes [54]. The expected acceleration of climate change and continuing pressure upon remnant urban habitat from insensitive development approaches, participatory approaches are especially pertinent, particularly when the aim is to better connect people with their local natural resources [54]. The emphasis upon citizen science and local stewardship as a function of this adaptive management is captured in the suggested principles described in Tables 1–3.

The proposed principles include a mixture of trialled approaches (observed in the case studies) and untested recommendations; therefore, future research will be needed to monitor the outcomes of operational level activities and trials to determine what works in terms of habitat preservation and regeneration as well as developer, municipality and market acceptability. The goal of such research is to develop approaches that result not simply in achieving an increase in Black Cockatoos, rather, this iconic species is seen as a vehicle for catalysing broader regenerative action. In the case of Perth, this relates to regenerating the threatened Banksia Woodland and its associated ecological assemblage. Nature-positive design and development needs to *over-compensate* for losses in other parts of the threatened bioregion, e.g., roads, agriculture. The adoption of cockatoo-sensitive urban design and development would benefit both cockatoos and citizens. The value of nature-positive design and development goes beyond the ecosystem service provision to include the immeasurable intrinsic value of a biodiverse habitat in this age of mass extinction. Such a demonstration would have significance for many other similar cities.

If these principles are to significantly reverse the decline of the Black Cockatoo population within Perth city and the broader bioregion then these measures would certainly require scaling through metropolitan-wide planning strategies and legislation. Harnessing the potential of nature-positive design and development supported by local stewardship, citizen science, planning controls and ongoing governance models (e.g., green trusts to set aside land in perpetuity with maintenance structures in place), ideally supported by planning policy to rapidly scale urban habitat increases—potentially catalysed by the emotive appeal of the vulnerable, but charismatic, Black Cockatoo.

## 6. Conclusions

The paper has described how urban development has begun to drive nature-positive outcomes in several locations in Perth. The benefits of such change are not singular though, as habitat expansion for an iconic species, such as the endangered Black Cockatoo also benefits other native species that share the same ecosystem habitat; while also providing co-benefits as ecosystem services and cultural ecosystem services for human populations. Regenerating species native to the local bioregion also presents developers with marketable project place qualities, and can instil civic pride amongst the local population by promoting placemaking qualities such as the site's authentic (biogeographical) identity.

Drawing upon these exemplars, the authorship team developed “cockatoo friendly” urban design principles with the goal that their use in urban planning might systematically increase the maintenance and repair of the remnant Banksia Woodland habitat as well as creating functionally regenerated urban ecosystems in the landscaping of the urban development with multiple biodiversity benefits. Observing successful outcomes resulting from the appeal of charismatic species to catalyse conservation activity, the authors suggest that the threatened, but iconic, Black Cockatoos can function as a leverage point to strengthen community and institutional support for nature-positive design and development in Perth. While some of the approaches have been observed to be successful in earlier trials, further work on the proposed “cockatoo friendly” urban design principles are needed and some proposals that are in preparation are likely to enable the framework to be tested.

The findings in this paper will hopefully assist the community, government and professional urban development practitioners, to begin to understand and enable such nature-positive urban design and development, especially the notion of using iconic species to help educate and build community interest in regenerative urbanism. This involves detailed work to identify the functional ecosystem that builds on what was there but enables it to regenerate biodiversity within an urban ecosystem. The adoption of nature-positive principles into the urban planning system is particularly important and does not seem to be beyond the remit or processes of the planning system. The mainstreaming into planning will require large developments to conclude that they can enable the financial and livability outcomes as well as the ecological outcomes at local and regional scales. Such conclusions would have global significance as all cities look to a future where nature-positive outcomes become increasingly important.

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