Received: 5 February 2021 | Revised: 30 May 2021 | Accepted: 14 July 2021

DOI: 10.1111/csp2.512

CONTRIBUTED PAPER

Conservation Science and Practice
A Journal of the Society for Conservation Biology
Open Access

WILEY

Biodiversity offsetting can relocate nature away from people: An empirical case study in Western Australia

Hanna Kalliolevo[1,2] | Ascelin Gordon[3] | Roshan Sharma[3] | Joseph W. Bull[4] | Sarah A. Bekessy[3]

[1]Department of Biology, University of Turku, Turku, Finland

[2]Natural Resources Institute Finland, Itäinen Pitkäkatu 4A, Turku, Finland

[3]School of Global Urban and Social Studies, RMIT University, Melbourne, Victoria, Australia

[4]Durrell Institute of Conservation and Ecology, School of Anthropology and Conservation, University of Kent, Canterbury, UK

Correspondence
Hanna Kalliolevo, Department of Biology, University of Turku, FI-20014 Turku, Finland.
Email: hamakal@utu.fi

Funding information
Koneen Säätiö; Linkage project, Grant/Award Number: LP160100324; ARC Discovery Project, Grant/Award Numbers: DP200103501, DP150103122

Abstract

Regular contact with nature provides multiple health benefits for people, but biodiversity is declining fast in an urbanizing world. Biodiversity offsets are implemented to compensate for the negative residual impacts of economic development projects on biodiversity, but the impacts on people who stand to lose biodiversity from their local environment are rarely considered. Offsetting typically involves creating, restoring or protecting biodiversity values at a specified site that can be located some distance away from the development site. In this article, we explore whether any relocation of nature is occurring due to development and offsets in Western Australia (WA); a jurisdiction with one of the world's few spatially referenced and comprehensive public offset registers. We analyzed data from 158 projects within the WA Environmental Offsets Register. We compared the location of development sites within 50 km (the urban and peri urban zone) and 500 km (~one day's drive) of the central business district (CBD) of Perth with the associated offset sites. The development and offset process together can be considered to contribute to a loss of urban nature as the offset sites tended to be further away from urban areas than the associated development sites. The offset sites were also located in significantly lower population density areas. However, offsets increased the publicly accessible land area by changing land ownership and creating amenity benefit by improving nature values on public land. Nevertheless, it is unclear to what extent relocation of nature further from people is balanced by increased public access to nature. In order to maintain nature connectedness, ecosystem service delivery and environmental justice in cities, we argue offset policies should require spatial proximity between impact and offset sites.

KEYWORDS

biodiversity loss, ecosystem services, environmental offsets, green space, nature connectedness, urban nature, wellbeing

1 | INTRODUCTION

Nature is declining at an unprecedented rate because of global land use changes (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, IPBES, 2019) that are threatening up to 25% of studied species with extinction, while monitored species populations have fallen by more than half since 1970 (World Wide Fund for Nature, 2020). At the same time as rapid negative changes in natural environments, it is becoming well established that the health and wellbeing of people is closely linked to access to nature and biodiversity (Hartig, Mitchell, de Vries, & Frumkin, 2014; Marselle, Stadler, Korn, Irvine, & Bonn, 2019; Millennium Ecosystem Assessment, MEA, 2005; Sandifer, Sutton-Grier, & Ward, 2015). Nature provides multiple ecosystem services from clean air and water to carbon sequestration and flood prevention (MEA, 2005). Regular nature experiences provide mental and physical benefits to people. A number of studies have shown several positive health effects of exposure to green areas (Frumkin et al., 2017; Twohig-Bennet & Jones, 2018). Greenness is associated with increased physical activity (James, Banay, Hart, & Laden, 2015), positive mental health (Houlden, Weich, Porto de Albuquerque, Jarvis, & Rees, 2018; Wood, Hooper, Foster, & Bull, 2017), reduced stress levels (Tyrväinen et al., 2014), lower incidence of allergies (Hanski et al., 2012; Ruokolainen et al., 2015), reduced obesity (Dadvand et al., 2014; Pereira et al., 2013), increased cognitive development of children (Dadvand et al., 2015) and better self-perceived general health (Triguero-Mas et al., 2015).

Despite the known benefits of having biodiverse green areas close to people, natural habitats continue to be cleared especially in and around urban areas for housing and infrastructure. One of the solutions to address this loss is biodiversity offsets, which are widely used around the world to compensate for the loss of biodiversity the development is causing (Global Inventory of Biodiversity Offset Policies, 2019). The idea of offsets is to compensate for the loss of biodiversity from development by protecting or restoring biodiversity on a different site. The typical aim of offsets is no net loss (NNL) or a net gain of biodiversity (Business and Biodiversity Offsets Program, BBOP, 2012). Despite advice to policy makers that local people should be considered by including stakeholder perspectives and evidence of local communities being satisfied and compensated for the losses (BBOP, 2012), the impacts on people who stand to lose biodiversity from their local environment are rarely considered (Jacob, Vaissiere, Bas, & Calvet, 2016; Sonter et al., 2018). Because offsetting allows destruction of habitat in one location to be compensated by biodiversity gains at a different location, it can create environmental injustice by spatially "relocating" nature and ecosystem services, with the potential for associated gains or losses in amenity and wellbeing for people living close to the offset or development sites. Ives and Bekessy (2015) raise concerns that offsetting may relocate nature away from people with associated loss of recreation and nature education opportunities. Risk of privatization of nature has also been raised (also Levrel, Scemama, & Vaissiere, 2017). The social sustainability of biodiversity offsetting schemes must be considered carefully (Ban et al., 2013; Jones et al., 2019) and good practice principles exist for ensuring NNL for people (Bull, Baker, Griffiths, Jones, & Milner-Gulland, 2018).

The loss and relocation of nature is particularly problematic in cities where residents typically have limited access to nature to start with. As already over half of the global human population now live in urban areas (United Nations, 2018), there is an urgent need to consider the preservation of nature, particularly in rapidly expanding cities. Despite the mainstreaming of green infrastructure in cities across Australia for delivering a wide range of co-benefits, vegetation cover continues to decrease (Amati et al., 2017). The same trend is occurring in the U.S. where the tree cover of urban areas has been annually decreasing by 36 million trees over a 5-year period (c. 2009–2014) (Nowak & Greenfield, 2018). Yet many jurisdictions are seeking to redress limited access to nature worldwide. The United Nations Sustainable Development Goals (2016) name "sustainable cities" as a target for 2030, including universal access to green spaces. Moreover, IPBES (2019) identifies maintaining and creating green spaces in cities as important for safeguarding urban biodiversity and ensuring the provision of ecosystem services. One of the main goals of Australia's Strategy for Nature (2019) is to connect people with nature and enrich the cities with nature by increasing the amount of green spaces and integrating urban ecology into landscape planning. With ever growing numbers of offset projects worldwide (Bull & Strange, 2018; Ives & Bekessy, 2015), the degree to which they disconnect people with nature in practice remains an open question.

There is an increasing amount of literature on how biodiversity offsets affect people by redistributing nature and the associated ecosystem services (Bull, Baker, et al., 2018; Griffiths, Bull, Baker, & Milner-Gulland, 2019; Jones et al., 2019; Sonter et al., 2018; Sonter et al., 2020). However, to our knowledge there are no studies examining the spatial location of offset sites compared to the development locations that generated them. Our study aims to fill this gap with an empirical case study from Perth, Western Australia (WA); a jurisdiction that maintains a unique offset database with the spatial locations of developments and their associated offsets (Government of Western Australia, 2020a), which enables us to explore patterns of offset location in an urban setting. The aim of this paper is to use the WA Environmental Offsets Register (EOR) to test our hypothesis that offsets are relocating nature away from people and cities. We test this by investigating (1) the distances between development sites and their associated offset sites, (2) whether the offset sites tend to be further from the center of Perth than their associated development sites, (3) the differences in the human population densities around development and offset sites, and (4) whether offsetting changes the public accessibility to green areas by changing the land tenure of project sites. We address questions regarding spatial redistribution of nature and its implications for local people and highlight the important role of nature in delivering ecosystem services close to people and improvements that could enhance the social sustainability of current offset systems.

2 | METHODS

2.1 | Study area and included offsets

The State of WA (Figure 1) comprises approximately one third of Australia's land area but has a population density of only about 1 person/km^2 due to the desert areas and inhospitable climate across much of the region. Approximately 75% of WA residents live in the state's capital city Perth (Figure 1) and its metropolitan area while over 90% of the total population lives in the southwest area ranging to a maximum 400 km from Perth, due to the favorable Mediterranean climate in this region (World Population Review, 2020).

Western Australia is a useful case study because the State has a comprehensive database of biodiversity offsets (the EOR; https://offsetsregister.wa.gov.au) that is a publicly available register of all offset agreements in WA. The register was launched in 2013 and aims to contribute to the transparency and accountability of offsets

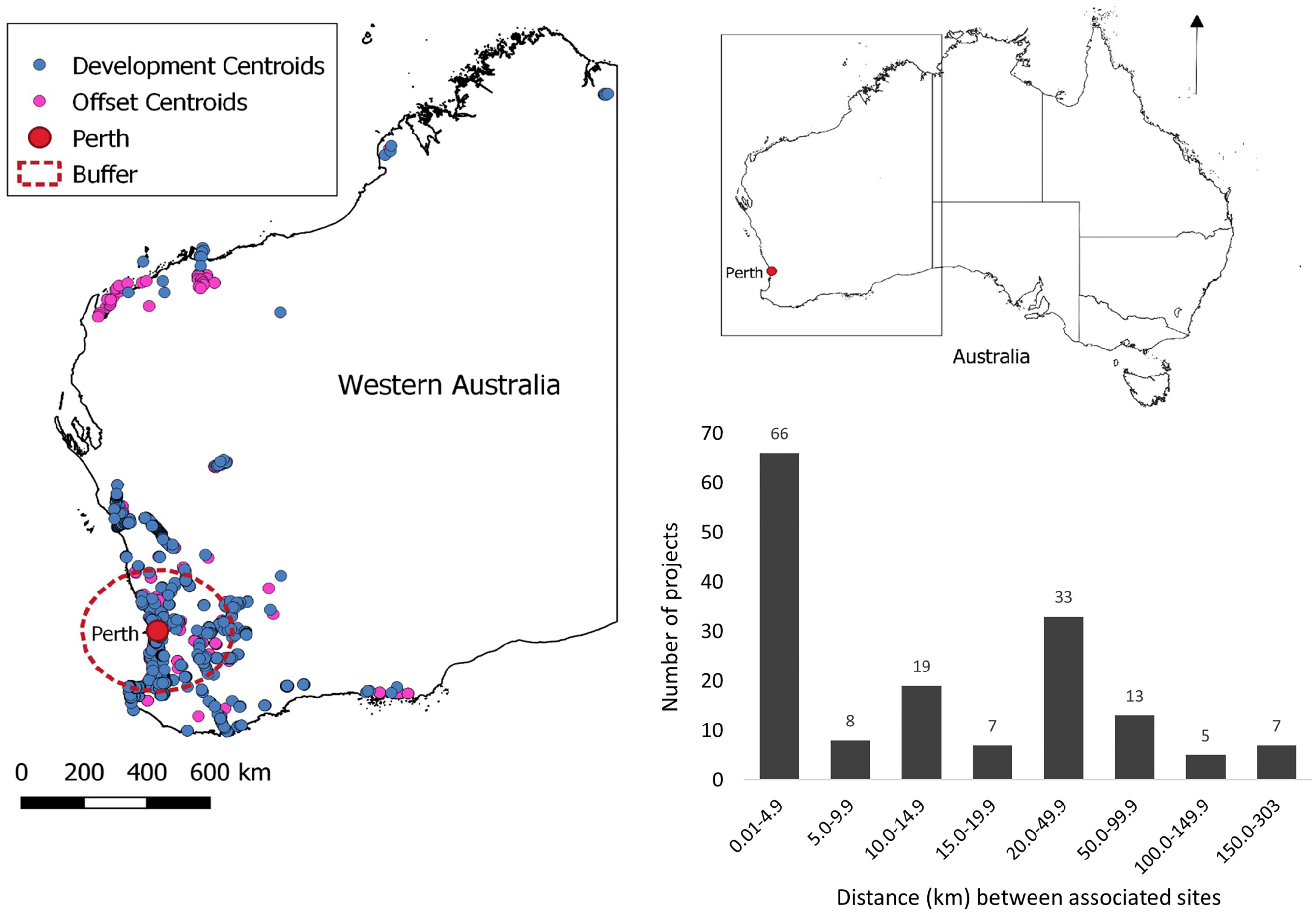

FIGURE 1 Map of Australia (top right), and a close up map of Western Australia (left), showing Perth, a 200 km buffer around Perth (red dashed line) and the centroids of the offset and development locations. The distribution of the distances between all development sites and their associated offset sites (where a development site has more than one offset associated with the mean distance of the site to all its offsets was used)

by offering information about the need and number of offsets, their locations, types and implementation activities (Government of Western Australia, 2014). Data has since been added to the register of offsets undertaken before the launch of the register, and it now includes offset decisions from 2003 onwards. The different offset types in the register include land acquisition, rehabilitation/restoration/on ground management, offset funds, recovery plans, research and other (e.g., monetary contribution, conservation covenant). Rehabilitation, restoration and on ground management refer to improvements made to the nature values of the site. Land acquisition means that the area is protected through a conservation covenant, allocation of the land to public reserve or some other form of binding agreement to maintain native vegetation on the property in perpetuity. Offset funds contribute directly to the biodiversity conservation, for example, by maintaining or establishing vegetation. Research offsets contribute to the scientific knowledge in protecting affected species and habitats. Our study included only offsets with maps identifying spatial location of development and offset sites (approximately 65% of all offsets in the register).

We received data in February 2019 from the Government of WA that maintains the EOR, as the spatial data were not yet downloadable directly from the site (since then the data have been made available on DataWA at https://catalogue.data.wa.gov.au/dataset/?q=offsets [Government of Western Australia, 2021]). The database included 244 projects with the spatial locations of the development areas, 159 that included the spatial locations of the offset areas and 158 projects with spatial locations of both areas. Hence, we were able to use 158 projects in our analysis, but the specific project numbers differed between analyses as they were based on different criteria. Table 1 summarizes the number of projects in different analyses. Some projects were divided into multiple development locations and developments could also correspond to one or more offset locations. The data include completed projects as well as current developments and offsets with specified locations.

TABLE 1 Summary of the analyses

Analysis	Included projects	Number of projects
Distance between associated development and offset sites	Projects with spatial locations in WA Offsets Register	158
Distance from Perth CBD	Projects with development sites within 500 km from Perth CBD Projects with development sites within 50 km from Perth CBD	147 52
Area size relation to distance from Perth CBD	Projects with development sites within 500 km from Perth CBD Projects with development sites within 50 km from Perth CBD	147 52
Population density	Offset and development sites inside 200 km buffer around Perth CBD	114
Yearly variation	Projects with development sites within 500 km from Perth CBD	147
Accessibility	Projects in the register with adequate land tenure information of all their sites	93

2.2 | Spatial analysis

We used QGIS 2.18.4 (2017) for the spatial analysis of the project sites. The spatial data were provided as a polygon layer depicting the offset and development sites. We created centroids for all of the polygons, and used a distance matrix to calculate the distance between all of the offset and development polygon centroids. Then we matched the offset sites with their associated development sites and calculated the distance between the development and offset locations, using the mean distance when there was more than one offset and/or development location.

We fixed a centroid for the Perth CBD polygon, and calculated the distance of offset and development areas to this CBD centroid. For our final analysis, we categorized projects into two groups: those with development sites 0–50 km from the CBD ($n = 52$), and those 0–500 km from the CBD ($n = 147$). We designated the actual urban area to be within 50 km distance from the CBD as the official Perth metropolitan area stretches approximately 125 km along the coast from Two Rocks to Singleton and about 50 km into east to The Lakes (Government of Western Australia, 2020b). The 500 km distance was assumed to be the maximum distance for an overnight trip to access nature from the CBD area (this area then encompasses >90% of all residents in WA). While the former analysis allowed us to evaluate relocation inside the city area, the latter allowed us to study the overall relocation of nature from the largest human settlement in WA. For this latter group we also conducted a temporal analysis to analyze if offsets were moving further from Perth CBD each year relative to developments. Moreover, we examined how the relationship between offset and development distance varied with time.

In order to analyze population densities, we obtained the latest Australian population grid data from the Australian Bureau of Statistics (2016). This was a raster layer with a pixel size of 1 km^2 containing population density information varying from 0 to almost 4,400 persons per km^2, calculated for the year 2016. We then downloaded a map of Local Government Area (LGA) of Australia as a polygon layer from the Australian Government (2014). The LGA areas of Perth, East, West, North and South Perth were dissolved to one polygon, and for that, we created a centroid with a 200 km buffer to also include the next two biggest cities (Mandurah and Bunbury) in WA. This buffer included 114 projects with six different offset types (rehabilitation, restoration, land acquisition, on ground management, offset funds and other) from 2006 to 2018. The offset fund type was included in the analysis because the monetary contribution was used in acquiring more land for protection and enhancement of nature values in a spatially mapped location. After this, we created a 1.5 km buffer around all the development and offset centroids inside the 200 km buffer to determine the population densities around these sites. Then we extracted the information from the raster data using the Point Sampling Tool to see the population density of each centroid point. We calculated the average population densities separately for development sites and offset sites and compared these values within a project.

In addition, we used the R software (4.0.3) and R packages sf, raster and tidyverse (R Core Team, 2020) to analyze if the size of the offsets increased with increasing distance from Perth separately for projects with development sites within 50 km and 500 km distances from Perth CBD.

2.3 | Land ownership and accessibility to nature

To investigate the possible changes in land tenure of project sites, we first determined the current tenure for the sites (either public or private land). Then we examined if the tenure had changed from what it had been before the establishment of offset or development on the area. Lastly, we calculated the amenity gain based on increased public land area and improved nature values that are created through restoration and on ground management that increase the natural values for example, by revegetating and restoring native vegetation, repairing ecosystem processes and managing weeds, disease or feral animals (WA Environmental Offsets Guideline 2014).

Division between public and private land was based on the same data received from the Government of WA that we used for spatial analysis. When the data sheet (available in attribute table in QGIS) did not provide all the information required, we used the EOR to complement the missing information on ownership. We were able to search for individual projects from the register and receive information on the land tenure about offsets from *Offset conditions* and *Offset Decision(s)* under each projects' details. Based on this information, we categorized each offset as to whether it occurred on public or private land. If the ownership could not be clearly identified, we categorized the offsets of private proponents' (e.g., private persons, companies) to be on private land and those of public proponents' (e.g., cities, departments, councils) to be on public land. When the offset was stated to be on the same property as development, it was counted to be private or public depending on the proponent.

In order to study the possible land tenure changes, we determined the previous ownership of the areas before they were established as offset sites. If offsets were created as land acquisition and the information stated "land to be ceded" then it was counted as being originally owned by the proponent unless stated otherwise. In case there was a monetary contribution for land acquisition, we could not identify the ownership of the purchased land. We used the same logic with development sites. All publicly owned land was considered accessible, and privately owned land was considered inaccessible, as entering private land in Australia is generally prohibited without explicit permission from the landowner whereas public land is in general publicly accessible.

We included only those projects where land tenure of all the offsets was clear as many projects had multiple offset sites and types. This ensured the reliable comparison between the land area lost and gained in offset and development sites. Offset types included rehabilitation, land acquisition, on ground management and other (conservation covenant). Our data included 95 projects with the required information, but we combined 4 projects into 2 pairs as these pairs shared the same offset site despite separate development sites. Hence, we studied the change in land ownership in 93 projects.

3 | RESULTS

3.1 | Distances between development areas and their associated offset sites

The offset dataset had 158 development-offset projects. Of these, 133 (84%) projects had offsets located less than 50 km away from development area(s) and 66 (42%)

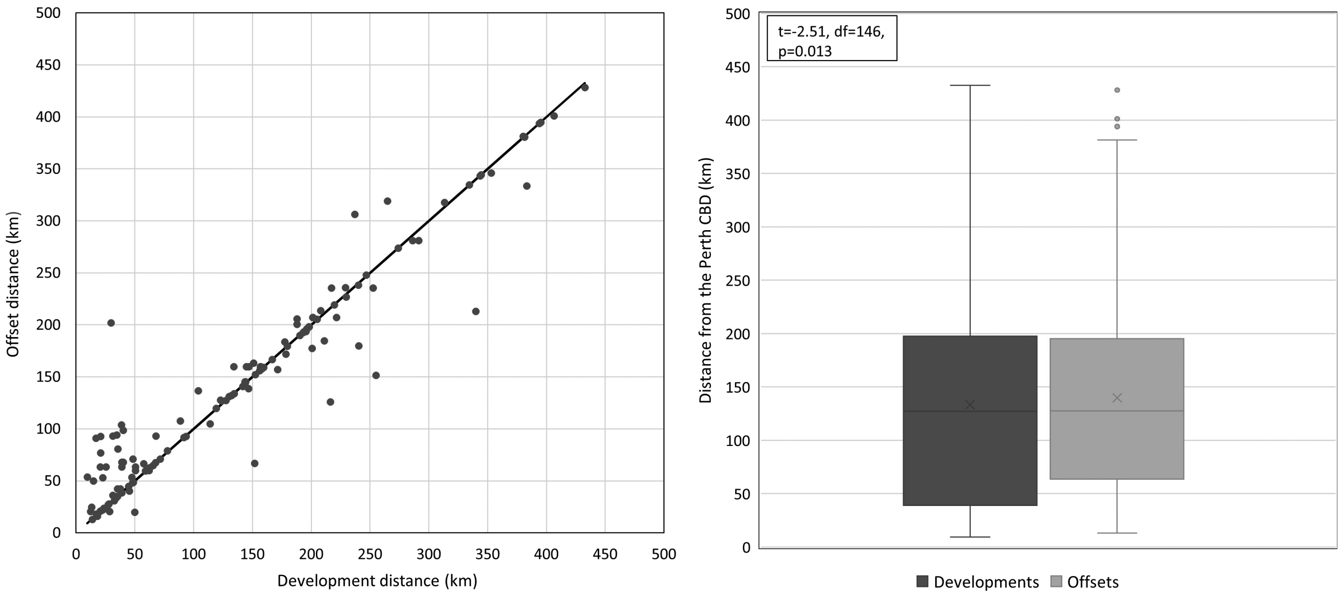

FIGURE 2 Offset and development site distances (km) from the Perth CBD for projects that have development site within 500 km from the CBD. The solid line on the left shows where the dots would fall if developments and their associated offsets were the same distance from the CBD

projects had offsets within 5 km of the development area(s) (Figure 1). However, 7 (4.4%) of the offset sites were more than 150 km away from their associated development sites. The mean distance between offset and development sites was 28.8 km while the greatest distance was 302.5 km.

3.2 | Distances of development and offset sites from Perth CBD

We calculated the distances of 147 projects that had development sites within 500 km from Perth CBD. The mean distance of development sites from Perth CBD was 133.5 km whereas for offset sites it was 139.8 km. The difference between the distances was significant when compared via a paired t-test ($t = -2.51$, df $= 146$, $p = .013$, $d = 0.21$) (Figure 2). The result was also highlighted within projects ($n = 52$) that had development sites maximum 50 km away from the CBD. In Figure 3, there are more points above the solid line, which is what would be expected when development sites are closer to the CBD than offset sites. We used Wilcoxon signed-rank to test this because the data were non-normally distributed. The test indicated that offsets were significantly further from the CBD than developments ($Z = 4.85$, $p < .001$, $r = 0.67$). The mean values also showed a clear difference as developments (mean = 31.4 km) were on average 22.9 km closer the CBD than offsets (mean = 54.3 km) (see box plots in Figure 3).

We evaluated the yearly variation of site distances ($n = 147$) from Perth CBD to test for any trend in offsets moving further away from the CBD than developments, but there was no clear significant difference when tested with regression ($t = -1.92$, df $= 146$, $p = .056$) (Figure 4a). The distance between associated sites did not vary between years ($t = 0.56$, df $= 146$, $p = .57$) (Figure 4b).

We found that for offsets that had their associated development site within 50 km from the CBD, there was an approximate tendency to increase in size with increasing distance from Perth CBD (Figure S1). The largest offset sites were located more than 200 km away from Perth, but outside of the 50 km radius, the area of offsets did not show any clear pattern of increasing with increasing distance from Perth CBD (Figure S2).

3.3 | Population densities around development and offset sites

Figure 5 shows the population densities around development and offset sites ($n = 114$). Most of the data points are located below the line indicating the population density tends to be higher around the development locations compared the offset locations. The mean population density around development sites was 315.7 person/km^2 while for offset sites it was 185.2 person/km^2. We used a natural log transformation with an added constant to allow the transformation of zero values. Then we compared the transformed values with a paired t-test showing significant difference ($t = 4.34$, df $= 113$, $p < .001$, $d = 0.34$) in population densities between the development and offset sites.

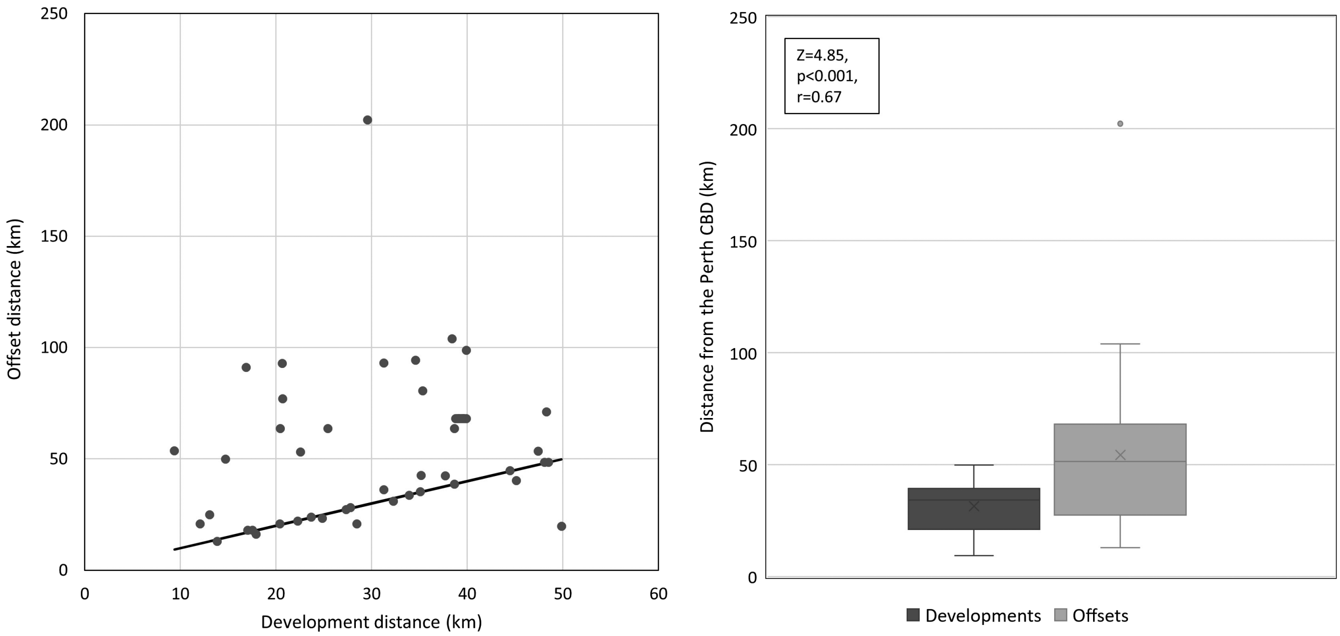

FIGURE 3 Offset and development site distances (km) from the Perth CBD for projects that have development site within 50 km from the CBD. The solid line on the left shows where the dots would fall if developments and their associated offsets were the same distance from the CBD

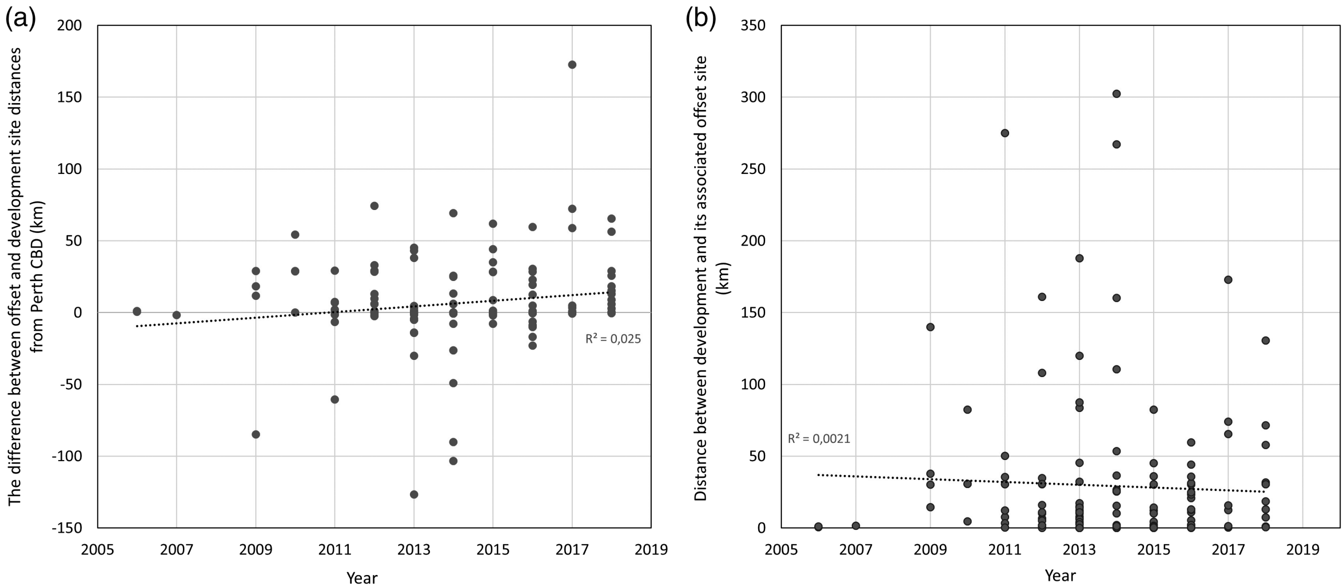

FIGURE 4 The difference between development site distance to Perth CBD and distance to Perth CBD for the associated offsets (left; negative values mean the development site was further away than the offset site), and the distance between developments site and their associated offsets over time (right)

3.4 | Nature accessibility

Based on our data, offsetting seemed to create more publicly accessible land and provide a gain in amenity (Table 2). Five offsets were created on newly formed public land that had been in private ownership. This created nearly 965 ha more publicly accessible land with no loss to land previously designated as public lands (as all developments were established on private lands). However, most of this new area was created by one compensation site with an area of 845 ha. This area was formed in a very sparsely populated area (0.2 people/km^2). All of these 5 offsets were land parcels ceded to the State of WA. The Department of Parks and Wildlife was to be

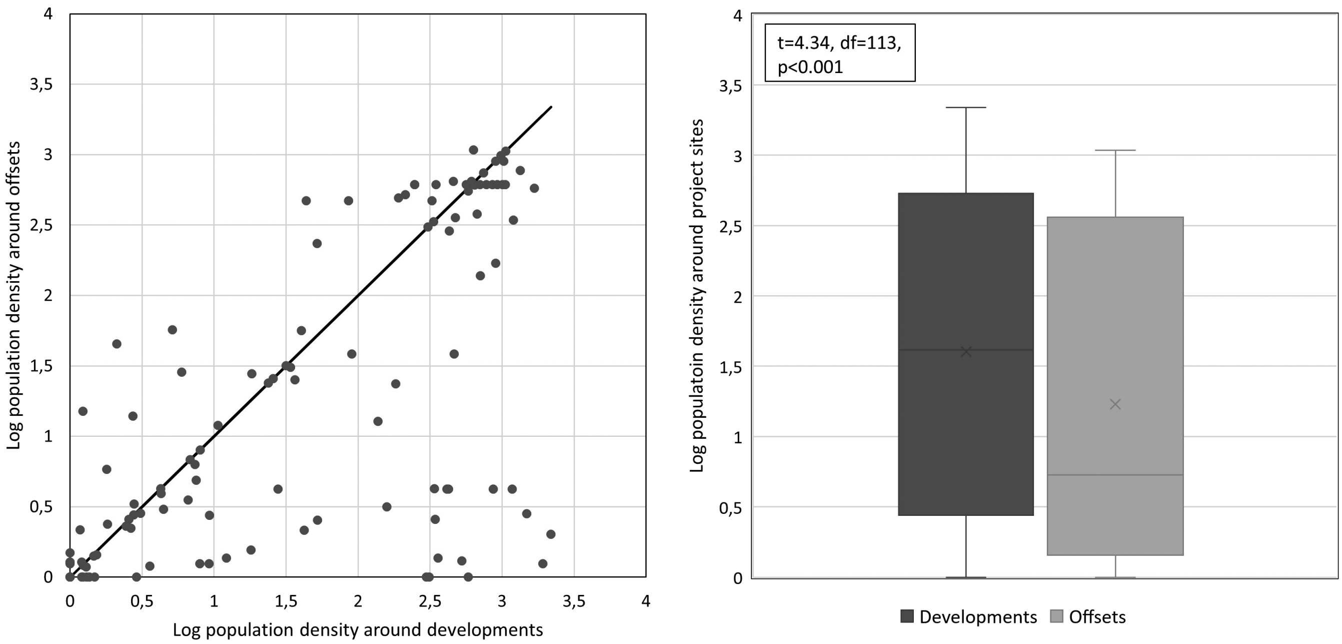

FIGURE 5 The natural log with an added constant transformed human population density around offset and development sites (left) with the solid line showing what would be expected if the densities around offsets and developments were the same. Box plots of the population densities around development and offset sites (right)

TABLE 2 Change of land tenure in project sites and the benefit for amenity based on increased public land area (ha) and increased nature values through restoration and on ground management

Change of land tenure	Amenity gain or improvement	Offset area (ha)	No. of projects[a]	Development area (ha)	No. of projects[b]	Total amenity benefit (ha)
Private ⟶ private	No	19,590	36	4,835	41	0
Private ⟶ public	Additional gain	965	5[c]	0	0	965
Public ⟶ public	Possible improvement	1,091	54	679	52	412
Public ⟶ private	Loss in amenity	0	0	0	0	0

[a]Offset projects.
[b]Development projects.
[c]Two projects are divided in 2 offset sites so that part of the offset remains on private and public land and part is transferred from private to public.

the responsible agency for the land in 4 of the offsets while one project did not yet provide information on the management authority of the offset site. All of the offset sites were to be conservation areas, two of them were to be attached to existing nature reserves, one was meant to form its own new nature reserve and two stated the site to be established as a conservation area. Most of the offsets (54) remained on public land which accounted for 1,091 ha (Table 2). This created a 412 ha improvement in amenity as the nature values in that area were to be improved by rehabilitation. Thirty-six offsets remained on private land accounting for 19,590 ha in total (one offset site being 18,000 ha and its development site 3,600 ha). None of the offset sites involved public land being converted to private tenure which would have created a loss of publicly accessible land.

4 | DISCUSSION

Our study provides empirical evidence of offsets relocating nature away from people by moving nature further from the city and to areas of lower population density. We show that close to Perth, the offsets tend to be further from the city center than the developments that generated them, but this trend is not so evident for developments and offsets further away. Even though the distance between associated development and offset sites was less than 5 km in 42% of the studied projects, offsets were still established in significantly less populated areas. These results are similar to BenDor, Brozovic, and Pallarhucheril (2007), who found wetlands relocating from urban to rural areas in US wetland mitigation programs. In addition, offsetting is resulting in urban greenspace being partly replaced with patches of native vegetation further away from the city. However, offsets are only one approach to managing urban biodiversity. We also found a trade-off between offset area size and distance from the urban center. The largest offset sites were those located further from the city and from people. This result follows the same pattern with our other findings that the difference is most evident in urban areas and decreases with increasing distance from the urban center.

A potential explanation for this pattern of relocation of nature is the lack of potential offset sites close to the development projects in and around urban areas. Furthermore, Fuller et al. (2010) discuss the cost-effectiveness of conservation sites and how protected areas compete with other land uses. This is likely affecting also the way offsets are located. Offsetting can be very expensive around the CBD and close to other growth areas due to high urban land prices. Developers naturally have an interest in creating the cheapest possible offsets, and might therefore purchase more land with cheaper price in rural areas than possible in urban areas. However, quantity is not all that matters and a larger site does not necessarily mean greater conservation benefits as the quality of these new protected sites need to be considered. It is possible that the increased area size further from the city is a result of developers having to compensate for a lower quality or suitability of an offset site. In addition, small habitat patches have an important role in conservation (Wintle et al., 2019). The additionality of offsets is likewise to be considered as offsetting in areas with low development pressures will likely deliver smaller gain compared to offsetting in urban areas where nature is under greater threat (Zu Ermgassen et al., 2020). Moreover, Bateman and Zonneweld (2019) argue that establishing offsets on the edge of urban areas might lead to net wellbeing losses and offsets should be targeted to areas where improved environments would create the greatest wellbeing benefits to people. There is international guidance suggesting that the impact that offsetting has on people's wellbeing should be considered (Jones et al., 2019) and offsetting in rural areas likely benefits the developer more than local people. Hence, offset gains constitute of area size along with equal importance to quality (biodiversity values of the site), location (supply and demand of ecosystem services) and accessibility (especially the possibility for recreation).

Relocation of nature further from populated areas has multiple consequences for people. Firstly, relocating nature even over a short distance can significantly change the ecosystem services provided to people in a local area. Griffiths et al. (2019) highlight the importance of including local people in decision-making processes throughout the project cycle. This way the use and cultural values of biodiversity can be included in the design of offsets that achieve NNL for local people. However, Sonter et al. (2018) found that less than half of the studied offset schemes considered ecosystem services. Sullivan and Hannis (2015) found that English non-governmental organizations were concerned that offsets would reduce access to nature by local communities and decrease the local value of particular places. Our results provide evidence that these concerns are not unfounded, at least for the case study we analyzed, but potentially for other sites as well.

Another problematic consequence of relocating nature to more politically and economically convenient sites is an overall decrease of nature in cities. Increasing separation between nature and people has been discussed as a particularly concerning trend in urban areas (Sullivan & Hannis, 2015). When nature moves further from the city, it decreases the useful ecosystem services contributing to human health and overall city functionality, such as reducing the urban heat island effect and preventing flooding (Niemelä et al., 2010). People also lose the multiple health benefits that nature provides: for example, access to green space can decrease mortality especially from respiratory diseases (Villeneuve et al., 2012). Many studies also suggest that proximity of nature is positively associated with physical activities (e.g., McMorris, Villeneuve, Su, & Jerrett, 2015). Engemann et al. (2019) support stronger integration of natural environments into urban planning and childhood life as green space during childhood improves mental health.

The offsets policy in WA does not directly require spatial proximity of offset sites; however, the site should be selected close to the development (WA Environmental Offsets Guideline 2014). In addition, the like-for-like requirement of WA offsets system can create difficulties in finding potential sites near the development. Nevertheless, in cases when it is impossible to find strictly similar environmental values, a more flexible solution is applied. However, using off-site and out-of-kind type of offsets creates philosophical challenges because biodiversity values are hard to compare with each other and the impacts and benefits to local human communities will be redistributed (Gonçalves, Marques, Soares, & Pereira, 2015).

Urban nature is not only important for human health. Cities are also biodiversity hotspots that host a variety of species (Ives et al., 2016; Seto, Güneralp, & Hutyra, 2012). In Australia, 40% of nationally threatened ecological communities are found in urban areas (Rodricks, 2010). Southwest Australia, where most of our development sites are located, is one of 36 global biodiversity hotspots (Critical Ecosystem Partnership Fund, 2020). This emphasizes the importance of preserving urban nature for the sake of native biodiversity.

Aerts, Honnay, and Nieuwenhuyse (2018) show associations between species diversity and human mental and physical wellbeing in green spaces. Their results indicate the relevance of the quality of green space that can provide habitat for urbanizing species. Diverse urban nature creates richer opportunities for environmental education. Additionally, closeness to nature in childhood helps to evolve a stronger connection between nature and individuals (Collado, Staats, & Corraliza, 2013; Dopko, Capaldi, & Zelenski, 2019). This on the other hand motivates people to become involved in conservation, as deeper connection to nature is associated with conservation activities (Barrera-Hernández, Sotelo-Castillo, Echeverría-Castro, & Tapia-Fonnlem, 2020; Whitburn, Linklater, & Abrahamse, 2019).

Even though offsetting draws nature further from people in our study, it can have potential benefits to the public by improving already accessible lands and creating new access to previously private land. Based on our results, offsets increase publicly accessible land by changing land ownership from private to public tenure. This happens when the project proponent cedes part of its privately owned land to public entities or buys privately owned lands for conversion to public tenure. Projects with both development and offset sites remaining as public land can generate benefit if the offset site is larger than the development site. Despite the increased amount of public land, these new accessible sites in our study have very low human population densities around them and so their benefit to people might be minimal. Furthermore, access to public land is not automatic and may require explicit mapping and signage. Public access can be problematic for conservation without ongoing appropriate management of potential impacts and some public offset sites can have limited accessibility in order to restore or protect vegetation on site. There can also be substantial time lags with restoration related offsets (Maron et al., 2012) and thus a temporal loss of public amenity values. Nevertheless, there is potential with changing land tenure when public conservation areas are extended by attaching previously private land to them or when individual land parcels in densely populated areas are made accessible. Overall, it is unclear from our study to what extent relocation is balanced by potential gains in amenity, but this is an important avenue for further research. In addition, May, Hobbs, and Valentine (2017) found that many offsets in the EOR did not result in planned outcomes. It is unclear whether or when offsets will be completed after agreed timeframes have been exceeded.

From the perspective of environmental justice, people losing nature near where they live should be compensated for their losses. Offset policies should therefore require spatial proximity of development and their associated offset sites. This would ensure the people losing proximity to nature and ecosystem services would be the ones to be compensated by offsets. However, finding ecologically equivalent sites can be difficult and biodiversity is the priority in offset schemes; there might be a need for additional criteria to ensure that people affected by the loss of nearby nature are compensated through the delivery of other nature experiences. This might be in addition to the ecological offset, which may by necessity need to be at a different site. One option could be integrating offsets into city planning to enhance urban greenness. As cities worldwide are increasingly interested in greening (City of Los Angeles, 2019; City of Melbourne, 2012; Greater London Authority, 2018), offsetting in urban areas could create an opportunity to improve and maintain urban nature that might otherwise lack funding. These urban offsets could be additional to ecological offsets to compensate for the lost benefits of ecosystem services to local residents, but only when the created benefit is truly additional, that is, would not have occurred without offset money and should not have been funded by other means (Maron, Gordon, Mackey, Possingham, & Watson, 2015).

As Sonter et al. (2020) point out, finding adequate land for ecological compensation to achieve NNL is not always possible, hence there is an urgent need to ensure that offset schemes lead to increased avoidance of biodiversity loss in the first place. Because of these various ecological, social and ethical reasons, there is a need to find new solutions to balance the conflict between development and conservation. Therefore, shifting away from offsets, towards onsite management of biodiversity values that means achieving biodiversity enhancement and development on the same site should also be enhanced.

We recognize there are limitations to our data and analysis. The available information for land ownership was scarce and we had to make assumptions regarding tenure. None of the projects in our dataset involved changing land tenure from public to private. However, there is a chance that in some private projects public land has been bought for private development since the EOR only states the project location, not the ownership nor how the development sites were acquired. Also, public land does not always imply public access. In addition, The EOR is an incomplete database that is being continuously updated. Hence, we were not able to use the full data of all the offsets undertaken in WA. It was also the case that 85 of the development sites (244 developments) did not have their offset site location included in the dataset and were therefore excluded from our study. This could be because the offset areas had yet to be decided, the offset comprising the funds for research, or possibly due to incomplete document management. We do not believe the exclusion of these developments would significantly bias results, as most of these developments would not have offset areas associated with them. Additionally, offset projects are complicated and not necessarily established as one offset site next to one development site, but as multiple sites that can share offsets from different development projects. Our data had for example a case of a large development area that was divided into smaller development projects. These development sites were all offset in the same location providing different amount of money and land parcels to create larger offset sites. We treated this case as separate projects as they were marked as such in the EOR, despite being subsets of a larger clearing permit. The overall development area had separate projects from 2 different proponents and the decisions for developments were made in different years.

Following from this study, it is important to analyze other biodiversity offset schemes worldwide to see if our findings are replicated elsewhere. Thus, responsible authorities should first establish comprehensive offset databases where the spatial data of development and associated offset sites would be stored. This kind of data is currently missing (Bull et al., 2018). However, further studies on the topic are important to ensure offsets are established in a way that considers local people and their rights to biodiverse environments. Regardless, this study highlights the importance of ensuring that offset systems do not reduce (and preferably increase) the proximity and accessibility of natural areas to the general public, particularly in urban contexts where those areas might be already scarce.

ACKNOWLEDGMENTS

Hanna Kalliolevo is funded by Koneen Säätiö. Sarah Bekessy and Ascelin Gordon were supported by ARC Discovery Project DP150103122 and Sarah Bekessy by ARC Discovery Project DP200103501 and Linkage project LP160100324. The authors would like to thank Western Australia Department of Water and Environmental Regulation for providing the data. We also thank Martine Maron and Mika Kurkilahti for technical support, Matti Salo and Timo Vuorisalo for their comments and two anonymous reviewers for their contributions to the manuscript.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

AUTHOR CONTRIBUTIONS

Hanna Kalliolevo, Sarah Bekessy, and Ascelin Gordon conceptualized and designed the study. Hanna Kalliolevo and Roshan Sharma analyzed the data. Hanna Kalliolevo drafted the manuscript with contributions from all authors.

DATA AVAILABILITY STATEMENT

Data used in this paper is available on DataWA at https://catalogue.data.wa.gov.au/dataset?q=offsets.

ORCID

Hanna Kalliolevo https://orcid.org/0000-0002-5400-4643

REFERENCES

Aerts, R., Honnay, O., & Nieuwenhuyse, V. A. (2018). Biodiversity and human health: Mechanisms and evidence of the positive health effects of diversity in nature and green spaces. *British Medical Bulletin*, *127*, 5–22.

Amati, M., Boruff, B., Caccetta, P., Devereux, D., Kaspar, J., Phelan, K., & Saunders, A. (2017). *Where should all the trees go? Investigating the impact of tree canopy cover on socio-economic status and wellbeing in LGA's prepared for Horticulture Innovation Australia Limited by the Centre for Urban Research*. Melbourne, VIC: RMIT University.

Australia's Strategy for Nature. (2019). Retrieved from https://www.australiasnaturehub.gov.au/national-strategy.

Australian Bureau of Statistics. (2016). Retrieved from http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/3218.02016?OpenDocument.

Australian Government. (2014). *WA Suburb/Locality Boundaries – PSMA Administrative Boundaries*. Retrieved from https://data.gov.au/dataset/ds-dga-6a0ec945-c880-4882-8a81-4dbcb85e74e5/details?q=perth%20administrative%20boundary.

Ban, N. C., Mills, M., Tam, J., Hicks, C. C., Klain, S., Stoeckl, N., … Chan, K. M. A. (2013). A social-ecological approach to conservation planning: Embedding social considerations. *Frontiers in Ecology and the Environment*, *11*, 194–202.

Barrera-Hernández, L. F., Sotelo-Castillo, M. A., Echeverría-Castro, S. B., & Tapia-Fonnlem, C. O. (2020). Connectedness to nature: Its impact on sustainable behaviors and happiness in children. *Frontiers in Psychology*, *11*, 276.

Bateman, I., & Zonneweld, S. (2019). *Building a better society: Net environmental gain from housing and infrastructure developments as a driver for improved social wellbeing*. UK2070 Commission.

BenDor, T., Brozovic, N., & Pallarhucheril, V. G. (2007). Assessing the socioeconomic impacts of wetland mitigation in the Chicago region. *Journal of the American Planning Association*, *73*, 263–282.

Bull, J., Baker, J., Griffiths, V. F., Jones, J. P. G., & Milner-Gulland, E. J. (2018). *Ensuring no net loss for people and biodiversity: Good practice principles*. Oxford, UK. https://doi.org/10.31235/osf.io/4ygh7

Bull, J. W., Brauneder, K., Darbi, M., Van Teeffelen, A. J. A., Quétier, F., Brooks, S. E., … Strange, N. (2018). Data transparency regarding the implementation of European 'no net loss' biodiversity policies. *Biological Conservation*, *218*, 64–72.

Bull, J. W., & Strange, N. (2018). The global extent of biodiversity offset implementation under no net loss policies. *Nature Sustainability*, *1*, 790–798.

Business and Biodiversity Offsets Program. (2012). *Standard on Biodiversity Offsets*. Washington, DC: BBOP.

City of Los Angeles. (2019). LA's new green deal. *Sustainability plan 2019*. Retrieved from https://plan.lamayor.org/.

City of Melbourne. (2012). *Urban forest strategy – Making a Great City Greener 2012–2032*. Retrieved from https://www.melbourne.vic.gov.au/community/greening-the-city/urban-forest/pages/urban-forest-strategy.aspx.

Collado, S., Staats, H., & Corraliza, J. A. (2013). Experiencing nature in children's summer camps: Affective, cognitive and behavioural consequences. *Journal of Environmental Psychology*, *33*, 37–44.

Critical Ecosystem Partnership Fund. (2020). Arlington, VA. Retrieved from https://www.cepf.net/our-work/biodiversity-hotspots.

Dadvand, P., Villanueva, C. M., Font-Ribera, L., Martinez, D., Basagaña, X., Belmonte, J., … Nieuwenhuijsen, M. J. (2014). Risks and benefits of green spaces for children: A cross-sectional study of associations with sedentary behavior, obesity, asthma, and allergy. *Environmental Health Perspectives*, *122*, 1329–1335.

Dadvand, P., Nieuwenhuijsen, M. J., Esnaola, M., Forns, J., Basagaña, X., Alvarez-Pedrerol, M., … Sunyer, J. (2015). Green spaces and cognitive development in primary schoolchildren. *Proceedings of the National Academy of Sciences of the United States of America*, *112*, 7937–7942.

Dopko, R. L., Capaldi, C. A., & Zelenski, J. M. (2019). The psychological and social benefits of a nature experience for children: A preliminary investigation. *Journal of Environmental Psychology*, *63*, 134–138.

Engemann, K., Bocker Pedersen, C., Arge, L., Tsirogiannis, C., Mortensen, P. B., & Svenning, J.-C. (2019). Residential green space in childhood is associated with lower risk of psychiatric disorders from adolescence into adulthood. *Proceedings of the National Academy of Sciences of the United States of America*, *116*, 5188–5193.

Frumkin, H., Bratman, G. N., Breslow, S. J., Cochran, B., Kahn, P. H., Jr., Lawler, J. J., … Wood, S. A. (2017). Nature contact and human health: A research agenda. *Environmental Health Perspectives*, *125*, 075001.

Fuller, R. A., McDonald-Madden, E., Wilson, K. A., Carwardine, J., Grantham, H. S., Watson, J. E. M., … Possingham, H. P. (2010). Replacing underperforming protected areas achieves better conservation outcomes. *Nature*, *466*, 365–367.

Global Inventory of Biodiversity Offset Policies. (2019). *International union for conservation of nature*. Durrell Institute for Conservation & Ecology: The Biodiversity Consultancy Retrieved from https://portals.iucn.org/offsetpolicy/

Gonçalves, B., Marques, A., Soares, A. M. V. D. M., & Pereira, H. M. (2015). Biodiversity offsets: From current challenges to harmonized metrics. *Current Opinion in Environmental Sustainability*, *14*, 61–67.

Government of Western Australia. (2014). *WA environmental offsets guidelines*. Perth: Government of Western Australia.

Government of Western Australia. (2020a). *The Environmental Offsets Register*. Retrieved from https://offsetsregister.wa.gov.au/public/searchregister/.

Government of Western Australia. (2020b). *Metropolitan region scheme*. Perth, Western Australia: Department of Planning, Lands and Heritage Retrieved from https://www.dplh.wa.gov.au/mrs

Government of Western Australia. (2021). *DataWA. Offsets register*. Retrieved from https://catalogue.data.wa.gov.au/dataset/?q=offsets.

Greater London Authority. (2018). *London environment strategy*. Retrieved from www.london.gov.uk.

Griffiths, V. F., Bull, J. W., Baker, J., & Milner-Gulland, E. J. (2019). No net loss for people and biodiversity. *Conservation Biology*, *33*, 76–87.

Hanski, I., von Hertzen, L., Fyhrquist, N., Koskinen, K., Torppa, K., Laatikainen, T., … Haahtela, T. (2012). Environmental biodiversity, human microbiota, and allergy are interrelated. *Proceedings of the National Academy of Sciences of the United States of America*, *109*, 8334–8339.

Hartig, T., Mitchell, R., de Vries, S., & Frumkin, H. (2014). Nature and health. *Annual Review of Public Health*, *35*, 207–228.

Houlden, V., Weich, S., Porto de Albuquerque, J., Jarvis, S., & Rees, K. (2018). The relationship between greenspace and the mental wellbeing of adults: A systematic review. *PLoS One*, *13*, 9.

IPBES (2019). In E. S. Brondizio, J. Settele, S. Díaz, & H. T. Ngo (Eds.), *Global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services*. Bonn, Germany: IPBES Secretariat.

Ives, C. D., & Bekessy, S. A. (2015). The ethics of offsetting nature. *Frontiers in Ecology and the Environment*, *13*, 568–573.

Ives, C. D., Lentini, P. E., Threlfall, C. G., Ikin, K., Shanahan, D. F., Garrard, G. E., … Kendal, D. (2016). Cities are hotspots for threatened species. *Global Ecology and Biogeography*, *25*, 117–126.

Jacob, C., Vaissiere, A. C., Bas, A., & Calvet, C. (2016). Investigating the inclusion of ecosystem services in biodiversity offsetting. *Ecosystem Services*, *21*, 92–102.

James, P., Banay, R. F., Hart, J. E., & Laden, F. (2015). A review of the health benefits of greenness. *Current Epidemiology Reports*, *2*, 131–142.

Jones, J. P. G., Bull, J. W., Roe, D., Baker, J., Griffiths, V. F., Starkey, M., … Milner-Gulland, E.-J. (2019). Net gain: Seeking better outcomes for local people when mitigating biodiversity loss from development. *One Earth*, *1*, 195–201.

Levrel, H., Scemama, P., & Vaissiere, A. C. (2017). Should we be wary of mitigation banking? Evidence regarding the risks associated with this wetland offset arrangement in Florida. *Ecological Economics*, *135*, 136–149.

Maron, M., Gordon, A., Mackey, B. G., Possingham, H. P., & Watson, J. E. M. (2015). Stop misuse of biodiversity offsets. *Nature*, *523*, 401–403.

Maron, M., Hobbs, R. J., Moilanen, A., Matthews, J. W., Christie, K., Gardner, T. A., … McAlpine, C. A. (2012). Faustian bargains? Restoration realities in the context of biodiversity offset policies. *Biological Conservation*, *155*, 141–148.

Marselle, M. R., Stadler, J., Korn, H., Irvine, K. N., & Bonn, A. (2019). *Biodiversity and health in the face of climate change*. Cham, Switzerland: Springer.

May, J., Hobbs, R. J., & Valentine, L. E. (2017). Are offsets effective? An evaluation of recent environmental offsets in Western Australia. *Biological Conservation*, *206*, 249–257.

McMorris, O., Villeneuve, P. J., Su, J., & Jerrett, M. (2015). Urban greenness and physical activity in a national survey of Canadians. *Environmental Research*, *137*, 94–100.

Millennium Ecosystem Assessment. (2005). *Ecosystems and human well-being: Biodiversity synthesis*. Washington, DC: World Resources Institute.

Niemelä, J., Saarela, S.-R., Söderman, T., Kopperoinen, L., Yli-Pelkonen, V., Väre, S., & Kotze, D. J. (2010). Using the ecosystem services approach for better planning and conservation of urban green spaces: A Finland case study. *Biodiversity and Conservation*, *19*, 3225–3243.

Nowak, D. J., & Greenfield, E. J. (2018). Declining urban and community tree cover in the United States. *Urban Forestry & Urban Greening*, *32*, 32–55.

Pereira, G., Christian, H., Foster, S., Boruff, B. J., Bull, F., Knuiman, M., & Giles-Korti, B. (2013). The association between neighborhood greenness and weight status: An observational study in Perth Western Australia. *Environmental Health*, *12*, 49.

R Core Team. (2020). *R: A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing.

Rodricks, S. (2010). TEEBcase: Biodiversity Banking and Offset Scheme of NSW, Australia. Mainly based on Department of Environment Climate Change and Water 2009 & Mamouney et al. 2009. Retrieved from http://www.teebweb.org/wp-content/uploads/2013/01/Biodiversity-Banking-and-Offset-scheme-New-South-Wales-Australia.pdf.

Ruokolainen, L., Hertzen, L., Fyhrquist, N., Laatikainen, T., Lehtomäki, J., Auvinen, P., … Hanski, I. (2015). Green areas around homes reduce atopic sensitization in children. *European Journal of Allergy and Clinical Immunology*, *70*, 195–202.

Sandifer, P. A., Sutton-Grier, A. E., & Ward, B. P. (2015). Exploring connections among nature, biodiversity, ecosystem services, and human health and well-being: Opportunities to enhance health and biodiversity conservation. *Ecosystem Services*, *12*, 1–15.

Seto, K. C., Güneralp, B., & Hutyra, L. R. (2012). Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. *Proceedings of the National Academy of Sciences*, *109*, 16083–16088.

Sonter, L. J., Gordon, A., Archibald, C., Simmonds, J. S., Ward, M., Metzger, J. P., … Maron, M. (2020). Offsetting impacts of development on biodiversity and ecosystem services. *Ambio*, *49*, 892–902.

Sonter, L. J., Gourevitch, J., Koh, I., Nicholson, C. C., Richardson, L. L., Schwartz, A. J., … Ricketts, T. H. (2018). Biodiversity offsets may miss opportunities to mitigate impacts on ecosystem services. *Frontiers in Ecology and the Environment*, *16*, 143–148.

Sonter, L. J., Simmonds, J. S., Watson, J. E. M., Jones, J. P. G., Kiesecker, J. M., Costa, H. M., … Maron, M. (2020). Local conditions and policy design determine whether ecological compensation can achieve no net loss goals. *Nature Communications*, *11*, 2072.

Sullivan, S., & Hannis, M. (2015). Nets and frames, losses and gains: Value struggles in engagements with biodiversity offsetting policy in England. *Ecosystem Services*, *15*, 162–173.

Triguero-Mas, M., Dadvand, P., Cirach, M., Martinez, D., Medina, A., Mompart, A., … Nieuwenhuijsen, M. J. (2015). Natural outdoor environments and mental and physical health: Relationships and mechanisms. *Environment International*, *77*, 35–41.

Twohig-Bennet, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research*, *166*, 628–637.

Tyrväinen, L., Ojala, A., Korpela, K., Lanki, T., Tsunetsugu, Y., & Kagawa, T. (2014). The influence of urban green environments on stress relief measures: A field experiment. *Journal of Environmental Psychology*, *38*, 1–9.

United Nations. (2016). *Sustainable development goals*. Retrieved from https://www.un.org/sustainabledevelopment/cities/.

United Nations. (2018). *The 2018 Revision of World Urbanization Prospects*. Population Division of the United Nations Department of Economic and Social Affairs (UN DESA).

Villeneuve, P. J., Jerrett, M., Su, J. G., Burnett, R. T., Chen, H., Wheeler, A. J., & Goldberg, M. S. (2012). A cohort study relating urban green space with mortality in Ontario, Canada. *Environmental Research*, *115*, 51–58.

Whitburn, J., Linklater, W., & Abrahamse, W. (2019). Meta-analysis of human connection to nature and proenvironmental behavior. *Conservation Biology*, *34*, 180–193.

Wintle, B. A., Kujala, H., Whitehead, A., Cameron, A., Veloz, S., Kukkala, A., … Bekessy, S. A. (2019). Global synthesis of conservation studies reveals the importance of small habitat patches for biodiversity. *Proceedings of the National Academy of Sciences of the United States of America*, *116*, 909–914.

Wood, L., Hooper, P., Foster, S., & Bull, F. (2017). Public green spaces and positive mental health – Investigating the relationship between access, quantity and types of parks and mental wellbeing. *Health & Place*, *48*, 63–71.

World Population Review. (2020). *Western Australia Population 2020*. Retrieved from https://worldpopulationreview.com/territories/western-australia-population/. Walnut, CA.

World Wide Fund for Nature (2020). In R. E. A. Almond, M. Grooten, & T. Petersen (Eds.), *Living Planet Report 2020 – Bending the curve of biodiversity loss*. Gland, Switzerland: WWF.

Zu Ermgassen, S. O. S. E., Maron, M., Corlet Walker, C. M., Gordon, A., Simmond, J., Strange, N., … Bull, J. W. (2020). The hidden biodiversity risks of increasing flexibility in biodiversity offset trades. *Biological Conservation*, *252*, 108861.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Kalliolevo, H., Gordon, A., Sharma, R., Bull, J. W., & Bekessy, S. A. (2021). Biodiversity offsetting can relocate nature away from people: An empirical case study in Western Australia. *Conservation Science and Practice*, *3*(10), e512. https://doi.org/10.1111/csp2.512