Urban green area provides refuge for native small mammal biodiversity in a rapidly expanding city in Ghana

Article *in* Environmental Monitoring and Assessment · August 2018

DOI: 10.1007/s10661-018-6858-1

5 authors, including:


Benjamin Yeboah Ofori
University of Ghana


Reuben Garshong
University of North Carolina at Greensboro


Francis Gbogbo
University of Ghana


Erasmus Owusu
University of Ghana

Environ Monit Assess (2018) 190:480
https://doi.org/10.1007/s10661-018-6858-1

Urban green area provides refuge for native small mammal biodiversity in a rapidly expanding city in Ghana

Benjamin Y. Ofori · Reuben A. Garshong · Francis Gbogbo · Erasmus H. Owusu · Daniel K. Attuquayefio

Received: 30 March 2018 / Accepted: 10 July 2018

Abstract Urbanization is a key driver of global biodiversity loss. Although sub-Saharan African countries are experiencing unprecedented urbanization and urban expansion, very little is known about how this impacts tropical biodiversity. Here, we assessed the effects of urban expansion and urban green space on local small mammal species diversity in Accra, Ghana. We surveyed small mammals in the University of Ghana botanical garden, an urban green area (UGA) and adjoining built-up environment (BE) and compared the results with baseline data (BLD) collected when large areas of the current city still remained mostly undeveloped. The methodology involved live-trapping using Sherman collapsible live-traps. Our data showed higher small mammal abundance and diversity in the UGA than BE. Similarity of species composition was higher between UGA and BLD than between BE and BLD. The small mammal species captured in BE (the rodents *Mastomys erythroleucus*, *Rattus rattus*, and *Arvicanthis rufinus*, and the shrew *Crocidura olivieri)* are known to easily adapt to human-modified landscapes. Our results suggest that urbanization negatively influenced the abundance, diversity, and community composition of small mammals. Efforts should be directed towards the integration of urban green areas into urban land development planning in developing countries in order to conserve local wildlife and ecological services that enhance the quality of urban life.

Keywords Anthropophilic species · Biotic homogenization · Environmental management · Landscape and urban planning · Urban biodiversity conservation · Urban green space · Accra Plains

B. Y. Ofori
Department of Biological Sciences, Macquarie University, North Ryde, Macquarie Park, NSW 2019, Australia

B. Y. Ofori · F. Gbogbo · E. H. Owusu · D. K. Attuquayefio
Department of Animal Biology and Conservation Science, University of Ghana, Legon, Accra, Ghana

B. Y. Ofori (✉)
Sydney, Australia

R. A. Garshong
Department of Biology, University of North Carolina, Greenboro, NC 27412, USA

Introduction

The world is becoming increasingly urban as a result of burgeoning urban human populations (Łopucki and Kiersztyn 2015). Cities still make up a relatively small percentage (~ 3%) of global land area (Schneider et al. 2010), even though over 50% of the world's population lives in urban areas (United Nations 2015). The proportion of urban dwellers is projected to increase further as global human populations continue to increase (Łopucki and Kiersztyn 2015). In general, more people in the developed world live in cities, but the largest cities and future urban growth are projected to occur in the developing world (Seto et al. 2012; Güneralp and Seto 2013). Rapid urbanization and urban expansion place enormous pressure on urban areas to provide high quality

Published online: 21 July 2018

of life for urban populations (McPhearson et al. 2016). Although urbanization and urban expansions remain important components of global land transformation processes, these pose enormous threats to the natural environment and global biodiversity (Seto et al. 2013; Sushinsky et al. 2013). Clearing of native vegetation to accommodate cities and associated built-up environment (human-constructed elements, such as buildings, roads, runways, and dams) causes habitat loss, reduction in species richness, and disappearance of disturbance-sensitive species (McKinney 2002; Shochat et al. 2010; Faeth et al. 2011; Scherner et al. 2013). It also causes increase in abundance of invasive and urban-tolerant (synurbic) species (Aronson et al. 2014; Gortat et al. 2014), leading to biotic homogenization (Łopucki and Kitowski 2016; McPhearson et al. 2016). Indeed, among the human activities that cause habitat loss and fragmentation, urbanization and urban expansion produce some of the highest rates of global ecological change, local extinctions, and native species declines (Pauchard et al. 2006; Seto et al. 2012; Aronson et al. 2014). Planning and managing urban land development in a biodiversity friendly manner poses a huge challenge for ecologists, urban land planners, and landscape designers.

Integration of urban green areas (UGA), defined as pieces of vegetated land within or adjoining urban areas, including parks, garden, and wetlands, into urban land development planning has become a global issue in recent times. These areas provide socio-ecological and conservation benefits that enhance the quality of urban life (McPhearson et al. 2016). For example, urban forest and other green spaces absorb pollutant particles from the environment (Beckett et al. 1998; Yang et al. 2005; Escobedo et al. 2011; Setälä et al. 2013; Janhäll 2015) and cool cities (Bowler et al. 2010; Oliveira et al. 2011; Maimaitiyiming et al. 2014) and provide esthetic and recreational services that improve the health and well-being of urban dwellers (Lee and Maheswaran 2011; Tyrväinen et al. 2014; Wolch et al. 2014; Ulmer et al. 2016). They also afford the opportunity for urban dwellers to connect with nature and to understand the ecological and evolutionary life-sustaining processes (Shwartz et al., 2014). Also, UGA provide habitats and refugia for numerous faunal species and native wildlife that are sensitive to urbanization (Kelcey 2015).

Although numerous studies from the developed world have demonstrated the socio-ecological and conservation benefits of urban green areas for city dwellers and urban biodiversity (McPhearson et al. 2016), such studies are strikingly uncommon in developing tropical countries (Pauchard et al. 2006; Faeth et al. 2011). As a result, the role of UGA in the conservation of native wildlife in most developing tropical countries is poorly understood. In fact, urban ecosystems and green areas in most developing countries, particularly sub-Saharan Africa, face constant threats from human encroachment, development, and management practices as a result of poor environmental consciousness and awareness of the importance of urban biodiversity and its associated ecological processes that enhance the general well-being and quality of urban life. For example, in Ghana, most urban forests and wetlands have been converted into settlements and economic ventures like filling stations (fuel shops), carwash bays, fitting shops, and supermarkets. Housing estate development for the high middle and upper classes have also failed to cater for urban green areas, largely due to poor environmental awareness and scarce locally gathered empirical evidence that demonstrates the social-ecological and conservation benefits of urban green areas.

Indeed, the effects of urbanization on biodiversity have been extensively studied in developed temperate cities, particularly Europe and North America (Faeth et al. 2011; Kowarik 2011; McPhearson et al. 2016). However, because the response of native biodiversity to urbanization varies among different climate zones (Lambin et al. 2001; Pauchard et al. 2006), studies from temperate countries alone cannot be extrapolated to a global scale. Therefore, there is a need to conduct similar studies in developing countries in order to obtain a more complete picture and nuanced understanding of the impact of urbanization and UGA on global urban biodiversity. The results of such studies can be used to support urban land development planning and landscape design in developing countries where rates of urbanization and urban expansion will be greatly increased in future (United Nations 2015).

The impact of urbanization on biodiversity has been mostly studied across urban-rural gradients in geographic space (McKinney 2008; Bennett and Gratton 2012; Łopucki and Kitowski 2016). This approach uses gradient analytical tools to assess species' distribution. It is intuitive to measure and provides useful framework for comparative studies on local, regional, and global scales (Niemelä and Kotze 2009; Gortat et al. 2014; Łopucki and Kitowski 2016). A second approach to studying effects of urbanization on biotic communities is to document changes through time in a single location (i.e., temporal rural-urban gradient) (McKinney 2006). Detailed comparisons of wildlife inventories at different times can show declines and/or alterations in species community composition. This method arguably provides a more robust evaluation of the effects of urbanization on biodiversity. However, it is rarely used because of lack of baseline data (McKinney 2006).

Small mammals are important component of biodiversity and constitute one of the common faunal species of urban ecosystems. They influence the structure and composition of urban ecosystems by feeding on seeds, seedlings, and insects as well as serving as pollinators and seed dispersal agents (David et al. 2015; Payne et al. 2016; Attuquayefio et al. 2017). They also serve as prey for carnivorous birds, mammals, and reptiles such as snakes and monitor lizards (Pearce and Venier 2005; Attuquayefio et al. 2017). Small mammals have specific habitat requirements and are intolerant of habitat disturbance (Peck et al. 2014). For these reasons, small mammal species abundance, diversity, and composition could reflect ecological trends in other species, making them good indicators of the ecological integrity of urban green areas.

Here, we investigated the impact of urbanization and urban green areas on native small mammal species in Accra, the rapidly expanding capital city of Ghana. Specifically, we assessed small mammal abundance, diversity, and community composition in the University of Ghana Botanical Garden, an urban green area (UGA) and adjoining built-up environment (BE) and compared it to baseline data (BLD) collected (in the late 1950s and from 1991 to 1992) when large areas of the current city of Accra were undeveloped and covered by native vegetation. We hypothesized that the UGA would harbor relicts of small mammal of the Accra Plains and higher species diversity than the BE. Our findings could provide the needed empirical data to support the integration of urban green areas into urban land development planning and landscape design to conserve urban biodiversity and ecological services that enhance the well-being of urban dwellers in Ghana and other sub-Saharan African countries.

Methodology

Study area

The University of Ghana Botanical Garden (UGA) (5° 39.38′ N, 0° 11.31′ W), which covers about 25 ha, is located on the main campus of the University of Ghana, Legon in Accra, Ghana (Fig. 1). The campus itself has a total area of 13,000 ha (13 km^2) and lies about 13 km north-east of the central business district of Accra. The climate and vegetation are typical of the Accra Plains, a geographically clearly defined area covering an area of 2800,000 ha (2800 km^2). Mean annual precipitation is distributed over major (May–July) and minor (September–October) rainy seasons and ranges from 733 to 1118 mm. The vegetation is mainly coastal savanna comprising of shrubs interspersed with thickets, woodland, and forest (Jenik and Hall 1976).

During the 1960–70s and until the late 1990s, large expanses of the Accra Plains were undeveloped and covered by native vegetation. Recently, however, rapid urbanization and urban expansion due to an ever-increasing urban population have led to massive clearing of the vegetation to provide houses and associated infrastructural development to accommodate the burgeoning urban population (Otoo et al. 2006). The Legon campus has also witnessed a recent rapid infrastructural development with increasingly expanding road networks and the construction of hostels, lecture theaters, buildings for departments, schools, centres, halls of residence, and staff to meet the demands of an increasing student population. This has dramatically reduced the green areas of the campus, although avenue trees like *Khaya senegalensis*, *Erythrophleum* sp., and *Millettia thonningii* continue to line the major roads (Garshong et al. 2013).

The UGA is one of the few urban green areas left in the city of Accra that harbor remnant vegetation of the Accra Plains, earning the description as "an island in a sea of urbanization" (Grimes 2006). It was established in 1950 to conserve indigenous and exotic plant species and to serve as a teaching/research facility and recreational area for the University and surrounding communities. It has since been managed to prevent encroachment, development, and other human activities that can compromise its ecological integrity. For the built-up environment (BE), we surveyed small mammals in grassland habitat surrounding residential buildings, lecture facilities, and along roads on the University of Ghana Legon campus (BE1) and at the Kotoka International Airport (BE2) (05° 35′ N, 00° 10′ W), which is located about 7.7 km from the University of Ghana, Legon. At both BE1 and BE2, an area of about 25 ha was randomly selected to small mammal survey.

The locations surveyed at BE2 were (i) Airside (Airport Runway, 05° 36.83′ N, 00° 09.95′ W), (ii) Airport

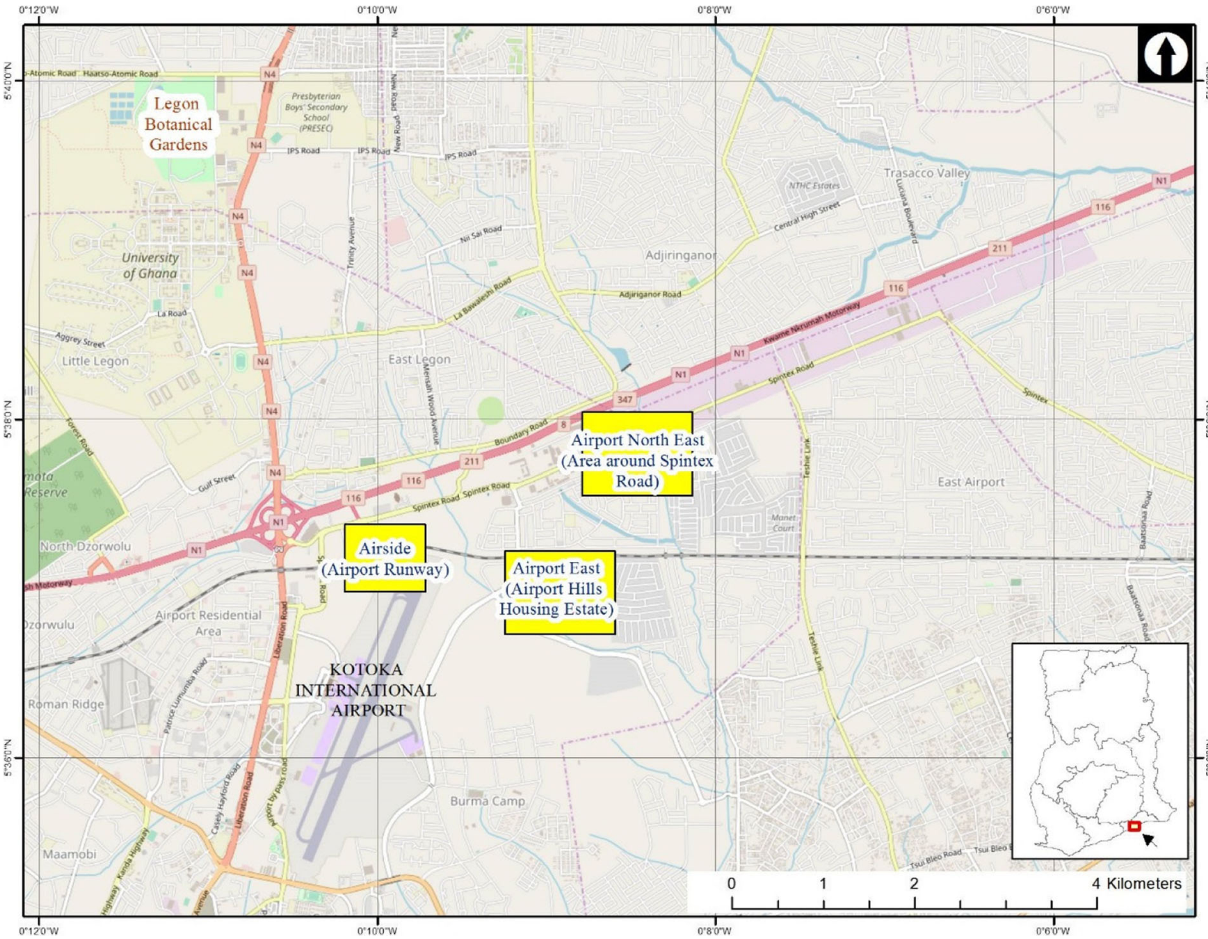

Fig. 1 Map of the western edge of the Accra Plains showing study sites at the University of Ghana, Legon campus, University of Ghana Botanical Garden (UGA), adjoining built environment (BE1), and Kotoka International Airport (BE2). Insert map showing location of the Accra Plains in southern Ghana

North-East (Spintex Road, 05° 37.16′ N, 00° 09.17′ W), and (iii) Airport East (Airport Hills Housing Estate, 05° 36.84′ N, 00° 09.96′ W) (Fig. 1). The Airside consists of the immediate surroundings of the tarmac, runway, apron, taxi, and hangar areas. This area of the airport comprises grasses, shrubby vegetation, and scattered structures (security checkpoint, airport fire hydrants, etc.). The Airport North-East is an area east of the runway along Spintex Road, characterized by a stream, an artificial water body created from sand mining activities, a railway track, some infrastructural development (private apartments, stores, etc.), and swampy vegetation. Airport East (Airport Hills Housing Estate) is a gated community with extensive infrastructural development and containing grassland habitat interspersed with the invasive neem trees (*Azadirachta indica*).

Live-trapping of small mammals

Small mammals were live-trapped using Sherman Collapsible Live-traps (23 × 9 × 7.5 cm) baited with a mixture of cornmeal and peanut butter. At the UGA, four transects, each of about 100 m, were established. One transect was placed in each of the different vegetation at the area (forest, woodland, thicket, and grassland). Ten baited traps were positioned along each transect at 10-m interval, giving a total of 40 traps set per night. Traps were set around 16:00 h GMT and inspected the next morning around 7:00 h GMT for four consecutive nights per month from January to May 2009 and 2014, giving a total of 1600 trap-nights.

At BE1, 20 baited traps were set along two transects, with inter-trap distances of 5–10 m. Traps were set for four consecutive nights per month from January to May 2009 and 2014, making a total of 1600 trap-nights. Additional trapping was conducted at BE1 in January 2018. Twenty traps were set between the student residence halls for seven consecutive nights. The overall number of trap-nights at BE1 was therefore 1740. At BE2, 20 baited traps were positioned along line transects established in each of the three sampling locations, with one trap per trap-station and inter-trap distance of 10 m. Traps (60 traps set per night) were set for 14 consecutive nights in June 2009, making a total of 840 trap-nights. Because BE2 is a security zone, we could not extend our trapping session beyond the duration that was granted by the area authority.

Captured individuals were identified on the spot, weighed, sexed, examined for reproductive condition, marked, and released at the point of capture. Voucher specimens that could not be immediately identified in the field were later deposited in the vertebrate museum of the Zoology Department of Animal Biology and Conservation Science (Zoology), University of Ghana. We used Rosevear (1969), Hutterer and Happold (1983), and Kingdon et al. (2013) as small mammal identification aids where necessary. Small mammal trapping and field handling techniques follow recommended guidelines for mammal fieldwork (Sikes and Mammalogists 2016) and taxonomy follows Wilson and Reeder (2005).

Small mammal baseline data

Baseline data for small mammals was obtained from Booth (1959), Grubb (1971), Decher et al. (1997), and Decher and Bahian (1999). Booth (1959) provided an annotated list of the terrestrial mammalian species of Accra Plains. The list included 13 species of rodents, three species of shrews and one hedgehog. Grubb (1971) extended the records of mammals from Ghana based on the collections of Angus Booth. Interestingly, all the small mammals reported for the Accra Plains by Grubb (1971) were listed by Booth (1959), except for the rodent *Graphiurus lorraineus*. The specimen of what is now considered *G. lorraineus* was captured in Achimota by Angus Booth and labeled *Graphiurus (Claviglis) spurrelli* in Booth (1959), also known as a Ghanaian subspecies of *G. murinus* (Rosevear 1969) described from Kumasi (Dollman, 1912). However, the geographic range of true *G. murinus* is now limited to East and South Africa. Decher et al. (1997) and Decher and Bahian (1999) reported three additional shrews (*Crocidura crossei*, *Crocidura buettikoferi*, and *Crocidura lamottei*) and one rodent (*Praomys derooi*, reported as *Myomys derooi*) from the Accra Plains. They re-assessed the diversity and structure of small mammal communities on the Accra Plains between November 1991 and June 1992 at six sites with different vegetation types: open savanna, primary forest, secondary forest, and thicket.

For comparison of species richness and composition among BLD, UGA, and BE, the BLD consisted of all the species reported for the Accra Plains by Booth (1959), Grubb (1971), Decher et al. (1997), and Decher and Bahian (1999). However, for comparison of abundance and diversity of species among BLD, UGA, and BE, we just used Decher and Bahian (1999) as baseline data because it is the only study that provided trapping effort and abundance of captured species. For ease of comparison, we pooled the data from their six sites to produce unified abundance and diversity estimates of small mammal species of the Accra Plains.

Data analysis

Trapping success of small mammals was estimated as the total number of captures per 100 trap-nights, where one trap-night equals one trap set for one night. We estimated species diversity using the Shannon-Wiener index and similarity of species composition among BLD, UGA, and BE using the Sørensen's index as follows:

$$SI = \frac{2c}{a+b}$$

where

- a number of species recorded at the first site,
- b number of species recorded at the second site, and
- c number of species common to both sites.

The significance of the difference in abundance and diversity of species between developed (i.e., BE1 and BE2) and undeveloped (BLD and UGA) areas was assessed using Fisher's exact test at alpha equals 0.05.

Results

Small mammal species abundance and diversity

Live-trapping of small mammals at UGA yielded 77 individuals of 11 species belonging to three orders: Rodentia (eight species), Insectivora (two species), and Erinaceomorpha (one species: African hedgehog, *Atelerix albiventrix*) in 1600 trap-nights. Trapping success was 4.8% with a Shannon-Wiener diversity index of $H' = 1.76$. The rodent species were *Arvicanthis rufinus* (reported as *A. niloticus rufinus* in Booth 1959), *Mastomys erythroleucus*, *Lophuromys sikapusi*, *Praomys derooi*, *P. tullbergi*, *Dasymys incomtus*, *Rattus rattus*, and *Mus musculoides*, while the shrews were *Crocidura olivieri* and *C. crossei.* The most abundant shrew and rodent species in the UGA were *Crocidura olivieri* and *A. rufinus* with 49.4 and 11.7% of the total captures, respectively (Table 1).

At BE1, 64 individuals of three rodent species (*M. erythroleucus*, *R. rattus*, and *A. rufinus*) and the shrew *C. olivieri* were captured in 17,400 trap-nights, while at BE2, 28 individuals of two rodents (*M. erythroleucus* and *A. rufinus*) and the shrew *C. olivieri* were captured in 840 trap-nights. Trapping success for BE1 and BE2 were 3.7 and 3.3%, respectively. The species diversity (Shannon-Wiener index) was 1.14 at B1 and 0.93 at B2. *Crocidura olivieri* was the most abundant species (54.7% of captures) at BE1, while *M. erythroleucus* dominated the captures at BE2 with 60.7% of the total captures (Table 1). The baseline study by Decher and Bahian (1999) yielded 258 individuals of 13 species comprising nine rodents and four shrews in 10,200 trap nights. Trapping success and species diversity were therefore 2.5% and 1.4, respectively. The captures were dominated by *P. tullbergi* (10.9%), followed by *Hylomyscus alleni* (10.9%), and *M. erythroleucus* (7%) (Table 1).

Similarity of species composition

The checklist of small mammals reported from the Accra Plains used as baseline data for comparison of similarity of species composition comprised six shrew species, 17 rodent species, and one hedgehog (Table 2). All the species captured at the UGA, BE1, and BE2 were previously reported for the Accra Plains. The similarity of species composition was higher (Sørensen's index = 0.63) between the UGA and BLD than between the BE1 and BLD (Sørensen's index = 0.29) and BE2 and BLD (Sørensen's index = 0.22). Thirteen species were recorded previously on the Accra Plains that were not recorded in the present study. These include the shrews *Crocidura lamottei*, *C. buettikoferi*, *C. poensis* and *Suncus megalura* (reported as *S. megalurus soricoides* by Booth 1959), and the rodents *Gerbilliscus kempi* (reported as *Tatera kempi*), *Graphiurus lorraineus*, *Hylomyscus alleni*, *Lemniscomys striatus*, *Lemniscomys barbarus*, *Mastomys huberti* (reported as *M. hildebrandtii* by Decher and Bahian 1999), *Uranomys ruddi*, and *Hybomys trivirgatus.*

Discussion

We hypothesized that the UGA should harbor relicts of the small mammals of the Accra Plains and higher diversity than BE1 and BE2. Our data supported this hypothesis. Small mammal species diversity were higher for BLD and UGA than BE1 and BE2, suggesting negative effects of urbanization on small mammals. The higher species diversity at UGA than the BE1 and BE2 and the higher similarity of species composition between UGA and BLD than between BE1 and BLD and BE2 and BLD suggest that UGA provided refuge for native small mammals. Although the differences in diversity and similarity of species composition between UGA and BE were not statistically significant (Fisher's exact test, $p > 0.05$), they are relevant in terms urban biodiversity conservation. Our findings support the results of previous studies on the negative impacts of urbanization on local wildlife.

Urbanization and urban expansion have been noted to radically alter small mammal and bird species composition, abundance, and diversity (Marzluff 2001; McKinney 2006; Cavia et al. 2009). For example, a study assessing the effects of human pressure and spatial landscape structure on small mammal species in an urban agglomeration found higher species richness and diversity in rural areas and city borders than urban areas (Gortat et al. 2014). The study also found high dissimilarity of species composition between rural and urban areas, with only the striped field mouse (*Apodemus agrarius*) common to rural and urban areas. The species *Apodemus flavicollis* (yellow-necked mouse) was captured at less developed areas only (Gortat et al. 2014). In their investigation of urban development on small

Table 1 Abundance and diversity of small mammal species at University of Ghana Botanical Garden (UGA), built environment at the University of Ghana, Legon (BE1), Kotoka International Airport (BE2), and baseline data (BLD) from Decher and Bahian (1999)

Small mammal species	Study locality			
Rodentia	UGA	BE1	BE2	BLD
Arvicanthis rufinus	9 (11.7%)	4 (6.3%)	6 (21.4%)	0
Gerbilliscus kempi	0	0	0	3 (1.2%)
Graphiurus lorraineus	0	0	0	6 (2.3%)
Hylomyscus alleni	0	0	0	28 (10.9%)
Dasymys incomptus	2 (2.6%)	0	0	0
Rattus rattus	2 (2.6%)	12 (18.8%)	0	0
Lemniscomys striatus	0	0	0	10 (3.9%)
Lophuromys sikapusi	5 (6.5%)	0	0	0
Mastomys erythroleucus	7 (9.1%)	13 (20.3%)	17 (60.7%)	18 (7.0%)
Mastomys huberti	0	0	0	2(0.8%
Mus musculoides	3 (3.9%)	0	0	9 (3.5%)
Praomys derooi	4 (5.2%)	0	0	0
Praomys tullbergi	5 (6.5%)	0	0	165 (64.0%)
Uranomys ruddi	0	0	0	3 (1.2%)
Soricomorpha				
Crocidura buettikoferi	0	0	0	1 (0.4%)
Crocidura crossei	1 (1.3%)	0	0	9 (3.5%)
Crocidura lamottei	0	0	0	1 (0.4%)
Crocidura olivieri	38 (49.4%)	35 (54.7%)	5 (17.9%)	0
Crocidura poensis	0	0	0	3 (1.2%)
Erinaceomorpha				
Atelerix albiventris	1 (1.3%)	0	0	0
Number of species	11	4	3	13
Number of all individuals	77	64	28	258
Number of trap-nights	1600	1740	840	10,200
Trap-success	4.8%	3.7%	3.3%	2.5%
Shannon-Wiener index	1.76	1.14	0.93	1.4

mammal assemblages of the Chilean Mediterranean zone, Fernández and Simonetti (2013) found higher small mammal abundance in rural forest fragments than urban forest fragments, the latter having a higher proportion of non-native rodents with no endemic species (Fernández and Simonetti 2013).

A recent study that evaluated the impacts of urbanization on a small mammal community also found declines in species richness and abundance, reduction in the abundance of urban sensitive species, and increase in synurbic species along a rural-urban gradient (Łopucki and Kitowski 2016). The study also found that green spaces in urban areas did not differ from rural sites in small mammal species abundance and diversity (Łopucki and Kitowski 2016). Our results corroborate previous studies conducted in temperate and tropical regions, as well as in small and big cities. We found higher species richness and diversity in an urban green area and baseline data collected at a time when the Accra Plains was still less-developed in many of today's built-up areas. Species community composition was altered in built-up areas. *Mastomys erythroleucus*, *Arvicanthis rufinus*, *Rattus rattus*, and *Crocidura olivieri* captured in built-up areas are somewhat adapted to human-modified landscapes. Our results support the assertion that only certain representatives of species persist in urban areas and that urban-intolerant species decline in abundance and eventually disappear from urban areas

Table 2 Species list of small mammals of the Accra Plains. BLD is baseline data compiled from Booth (1959), Grubb (1971), Decher et al. (1997), and Decher and Bahian (1999). UGA, BE1, and BE2 are data from the present study

Small mammal species	Study locality			
Rodentia	UGA	BE1	BE2	BLD
Arvicanthis rufinus	✓	✓	✓	✓
Gerbilliscus kempi				✓
Graphiurus lorraineus				✓
Hylomyscus alleni				✓
Dasymys incomptus	✓			✓
Rattus rattus	✓	✓		✓
Lemniscomys striatus				✓
Lemniscomys barbarus				✓
Lophuromys sikapusi	✓			✓
Mastomys erythroleucus	✓	✓	✓	✓
Mastomys huberti				✓
Mus musculoides	✓			✓
Praomys derooi	✓			✓
Hybomys trivirgatus				✓
Praomys tullbergi	✓			✓
Uranomys ruddi				✓
Soricomorpha				
Crocidura buettikoferi				✓
Crocidura crossei	✓			✓
Crocidura lamottei				✓
Crocidura olivieri	✓	✓	✓	✓
Suncus megalura				✓
Crocidura poensis				✓
Erinaceomorpha				
Atelerix albiventris	✓			✓

(Cavia et al. 2009; Lättman et al. 2014; Sol et al. 2014; Vakhlamova et al. 2014; Łopucki and Kitowski 2016).

The marked difference in vegetation structure between urban and natural landscapes could be implicated for the pattern of wildlife species declines across rural-urban gradients. In general, urban habitats tend to be similar in terms of ecological structures, functions, and constraints, irrespective of biogeographical location (Savard et al. 2000; Clergeau et al. 2001). Infrastructural development on the University of Ghana Legon campus and at Kotoka International Airport was the main factor causing the changes in small mammal species diversity and composition. The higher small mammal species diversity in the UGA suggests that cities have the potential to maintain a high level of biodiversity and urban sensitive wildlife species if appropriately planned to incorporate urban green areas. This means that effort should be channeled toward conserving the other green areas in Accra, including the Achimota forest, the Korle, Sakumo, and the Kpeshie Lagoon areas.

As rapid urbanization continues unabated in developing countries, deliberate effort is required to minimize its impact on native urban wildlife species. Local and urban authorities should enforce the integration of urban green spaces into urban land planning. Remnant natural plant communities may harbor native wildlife species and should be maintained as urban green areas during urban expansions. Indigenous tree species should be planted in area that are demarcated for green spaces, but where remnant vegetation is non-existent. It is also important that urban dwellers and commercial areas have very minimal effect on urban green spaces (Hostetler et al. 2011). Indeed, human preferences are a key criterion in the design of urban green areas. Reconciling the opposing economic and ecological needs for urban land development in developing countries, requires clear specifications of motivation for the latter and effective communication to planners, developers, and urban residents. Evidence suggest that preferences for urban green areas increased for people who knew the names of the species or who were provided information about birds found in urban green areas (Caula et al. 2009; Cox and Gaston 2015). Urban dwellers will be more likely to pay for and protect urban green areas if they are well-informed about the importance of biodiversity in sustaining city life (Allum et al. 2008; Shwartz et al. 2014).

Increasing public knowledge and awareness of urban biodiversity conservation could be achieved with outreach programs. Conservation education could be integrated into primary and secondary school curricula. Public campaigns that highlight wildlife and plant species, particularly endangered and rare biota harbored by urban green areas, as well as the benefits humans derive from such areas, could help increase environmental awareness. This could be done by posters, competition about environmental conservation, arranging television and radio programs, and websites related to urban ecosystem conservation. Increased public awareness of the benefits of urban green areas will provide the needed impetus for city planners and policy-makers to integrate urban green areas into urban land development planning and landscape design.

Acknowledgements The Management of the Kotoka International Airport, Accra-Ghana gave permission for the small mammal survey to be undertaken at the airport area.

References

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: a meta-analysis. *Public Understanding of Science, 17*(1), 35–54.

Aronson, M. F., La Sorte, F. A., Nilon, C. H., Katti, M., Goddard, M. A., Lepczyk, C. A., et al. (2014). A global analysis of the impacts of urbanization on bird and plant diversity reveals key anthropogenic drivers. *Proceedings of Biological Science, 281*(1780), 20133330. https://doi.org/10.1098/rspb.2013.3330.

Attuquayefio, D. K., Owusu, E. H., & Ofori, B. Y. (2017). Impact of mining and forest regeneration on small mammal biodiversity in the western region of Ghana. *Environmental Monitoring and Assessment, 189*(5), 237–245.

Beckett, K. P., Freer-Smith, P., & Taylor, G. (1998). Urban woodlands: their role in reducing the effects of particulate pollution. *Environmental Pollution, 99*(3), 347–360.

Bennett, A. B., & Gratton, C. (2012). Local and landscape scale variables impact parasitoid assemblages across an urbanization gradient. *Landscape and Urban Planning, 104*(1), 26–33.

Booth, A. H. (1959). On the mammalian fauna of the Accra Plain. *Journal of the West African Science Association, 5*, 26–36.

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S. (2010). Urban greening to cool towns and cities: a systematic review of the empirical evidence. *Landscape and Urban Planning, 97*(3), 147–155.

Caula, S., Hvenegaard, G. T., & Marty, P. (2009). The influence of bird information, attitudes, and demographics on public preferences toward urban green spaces: The case of Montpellier, France. *Urban Forestry & Urban Greening, 8*(2), 117–128.

Cavia, R., Cueto, G. R., & Suárez, O. V. (2009). Changes in rodent communities according to the landscape structure in an urban ecosystem. *Landscape and Urban Planning, 90*(1), 11–19.

Clergeau, P., Jokimäki, J., & Savard, J. P. L. (2001). Are urban bird communities influenced by the bird diversity of adjacent landscapes? *Journal of Applied Ecology, 38*(5), 1122–1134.

Cox, D. T., & Gaston, K. J. (2015). Likeability of garden birds: Importance of species knowledge & richness in connecting people to nature. *PLoS One, 10*(11), e0141505.

David, J. P., Manakadan, R., & Ganesh, T. (2015). Frugivory and seed dispersal by birds and mammals in the coastal tropical dry evergreen forests of southern India: a review. *Tropical Ecology, 56*(1), 41–55.

Decher, J., & Bahian, L. K. (1999). Diversity and structure of terrestrial small mammal communities in different vegetation types on the Accra Plains of Ghana. *Journal of Zoology, 247*(3), 395–408.

Decher, J., Schlitter, D. A., & Hutterer, R. (1997). Noteworthy records of small mammals from Ghana with special emphasis on the Accra Plains. *Annals of Carnegie Museum, 66*, 209–227.

Dollman, G. (1912). Seven new African dormice. *Annals and Magazine of Natural History, Ser, 8*(9), 312–320.

Escobedo, F. J., Kroeger, T., & Wagner, J. E. (2011). Urban forests and pollution mitigation: analyzing ecosystem services and disservices. *Environmental Pollution, 159*(8), 2078–2087.

Faeth, S. H., Bang, C., & Saari, S. (2011). Urban biodiversity: patterns and mechanisms. *Annals of the New York Academy of Sciences, 1223*(1), 69–81.

Fernández, I. C., & Simonetti, J. A. (2013). Small mammal assemblages in fragmented shrublands of urban areas of Central Chile. *Urban Ecosystems, 16*(2), 377–387.

Garshong, R., Attuquayefio, D., & Gbogbo, F. (2013). Development on small mammal diversity and abundance on the Legon campus of the University of Ghana. *West African Journal of Applied Ecology, 21*(2), 1–9.

Gortat, T., Barkowska, M., Tkowska, A. G.-S., Pieniążek, A., Kozakiewicz, A., & Kozakiewicz, M. (2014). The effects of urbanization—small mammal communities in a gradient of human pressure in Warsaw city, Poland. *Polish Journal of Ecology, 62*(1), 163–172.

Grimes, L. G. (2006). Avifaunal and environmental changes on the campus of the University of Ghana, Legon, between the 1960s and 2004. *Malimbus, 28*(1), 57–68.

Grubb, P. (1971). Further records of mammals from Ghana, based on the collections of Angus Booth. *Revue de Zoologie et de Botanique Africaines, 84*, 192–202.

Güneralp, B., & Seto, K. (2013). Futures of global urban expansion: uncertainties and implications for biodiversity conservation. *Environmental Research Letters, 8*(1), 014025.

Hostetler, M., Allen, W., & Meurk, C. (2011). Conserving urban biodiversity? Creating green infrastructure is only the first step. *Landscape and Urban Planning, 100*(4), 369–371.

Hutterer, R., & Happold, D. C. D. (1983). The shrews of Nigeria. *Bonner Zoologische Monographien, 18*, 1–79.

Janhäll, S. (2015). Review on urban vegetation and particle air pollution–deposition and dispersion. *Atmospheric Environment, 105*, 130–137.

Jeník, J., & Hall, J. B. (1976). Plant communities of the Accra Plains, Ghana. *Folia Geobotanica et Phytotaxonomica, Praha, 11*, 163–212.

Kelcey, J. G. (2015). Vertebrates and invertebrates of European cities: selected non-avian Fauna: Springer, Boston, MA, USA.

Kingdon, J., Happold, D., Butynski, T., Hoffmann, M., Happold, M., & Kalina, J., Eds. (2013). Mammals of Africa (6 vols.), Bloomsbury Publishing, London

Kowarik, I. (2011). Novel urban ecosystems, biodiversity, and conservation. *Environmental Pollution, 159*(8), 1974–1983.

Lambin, E. F., Turner, B. L., Geist, H. J., Agbola, S. B., Angelsen, A., Bruce, J. W., et al. (2001). The causes of land-use and land-cover change: moving beyond the myths. *Global Environmental Change, 11*(4), 261–269.

Lättman, H., Bergman, K. O., Rapp, M., Tälle, M., Westerberg, L., & Milberg, P. (2014). Decline in lichen biodiversity on oak trunks due to urbanization. *Nordic Journal of Botany, 32*(4), 518–528.

Lee, A. C., & Maheswaran, R. (2011). The health benefits of urban green spaces: a review of the evidence. *Journal of Public Health, 33*(2), 212–222.

Łopucki, R., & Kiersztyn, A. (2015). Urban green space conservation and management based on biodiversity of terrestrial fauna–a decision support tool. *Urban Forestry & Urban Greening, 14*(3), 508–518.

Łopucki, R., & Kitowski, I. (2016). How small cities affect the biodiversity of ground-dwelling mammals and the relevance of this knowledge in planning urban land expansion in terms of urban wildlife. *Urban Ecosystems, 20*(4), 1–11.

Maimaitiyiming, M., Ghulam, A., Tiyip, T., Pla, F., Latorre-Carmona, P., Halik, Ü., Sawut, M., & Caetano, M. (2014). Effects of green space spatial pattern on land surface temperature: implications for sustainable urban planning and climate change adaptation. *ISPRS Journal of Photogrammetry and Remote Sensing, 89*, 59–66.

Marzluff, J. M. (2001). Worldwide urbanization and its effects on birds. Pp. 19–47. In Avian ecology and conservation in an urbanizing world (J. M. Marzluff, R. Bowman & R. Donnelly, eds.) Springer, Boston, MA, USA.

McKinney, M. L. (2002). Urbanization, biodiversity, and conservation: the impacts of urbanization on native species are poorly studied, but educating a highly urbanized human population about these impacts can greatly improve species conservation in all ecosystems. *Bioscience, 52*(10), 883–890.

McKinney, M. L. (2006). Urbanization as a major cause of biotic homogenization. *Biological Conservation, 127*(3), 247–260.

McKinney, M. L. (2008). Effects of urbanization on species richness: a review of plants and animals. *Urban Ecosystems, 11*(2), 161–176.

McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., Weber, C., Haase, D., Breuste, J., & Qureshi, S. (2016). Advancing urban ecology toward a science of cities. *BioScience, 66*(3), 198–212. https://doi.org/10.1093/biosci/biw002.

Niemelä, J., & Kotze, D. J. (2009). Carabid beetle assemblages along urban to rural gradients: a review. *Landscape and Urban Planning, 92*(2), 65–71.

Oliveira, S., Andrade, H., & Vaz, T. (2011). The cooling effect of green spaces as a contribution to the mitigation of urban heat: a case study in Lisbon. *Building and Environment, 46*(11), 2186–2194.

Otoo, E. A., Whyatt, D. J., & Ite, U. E. (2006). Quantifying urban growth in Accra Metropolitan Area (AMA), Ghana and exploring causal mechanisms. Paper presented at the 5th FIG Regional Conference (PP. 8–11).

Pauchard, A., Aguayo, M., Peña, E., & Urrutia, R. (2006). Multiple effects of urbanization on the biodiversity of developing countries: the case of a fast-growing metropolitan area (Concepción, Chile). *Biological Conservation, 127*(3), 272–281.

Payne, S. L., Symes, C. T., & Witkowski, E. T. (2016). Of feathers and fur: differential pollinator roles of birds and small mammals in the grassland succulent Aloe peglerae. *Austral Ecology, 41*(8), 952–963.

Pearce, J., & Venier, L. (2005). Small mammals as bioindicators of sustainable boreal forest management. *Forest Ecology and Management, 208*(1), 153–175.

Peck, M. R., Maddock, S. T., Morales, J. N., Oñate, H., Mafla-endara, P., Peñafiel, V. A., et al. (2014). Cost-effectiveness of using small vertebrates as indicators of disturbance. *Conservation Biology, 28*(5), 1331–1341.

Rosevear, D. R. (1969). The rodents of West Africa: trustees of the British Museum (natural history).

Savard, J.-P. L., Clergeau, P., & Mennechez, G. (2000). Biodiversity concepts and urban ecosystems. *Landscape and Urban Planning, 48*(3), 131–142.

Scherner, F., Horta, P. A., de Oliveira, E. C., Simonassi, J. C., Hall-Spencer, J. M., Chow, F., et al. (2013). Coastal urbanization leads to remarkable seaweed species loss and community shifts along the SW Atlantic. *Marine Pollution Bulletin, 76*(1), 106–115.

Schneider, A., Friedl, M. A., & Potere, D. (2010). Mapping global urban areas using MODIS 500. m data: New methods and datasets based on 'urban ecoregions'. *Remote Sensing of Environment, 114*(8), 1733–1746.

Setälä, H., Viippola, V., Rantalainen, A.-L., Pennanen, A., & Yli-Pelkonen, V. (2013). Does urban vegetation mitigate air pollution in northern conditions? *Environmental Pollution, 183*, 104–112.

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*(40), 16083–16088.

Seto, K. C., Parnell, S., & Elmqvist, T. (2013). A global outlook on urbanization. Pp. 1–12 in urbanization, biodiversity and ecosystem services: challenges and opportunities (T. Elmqvist et al. eds). Springer Netherlands. https://doi.org/10.1007/978-94-007-7088-1.

Shochat, E., Lerman, S., & Fernández-Juricic, E. (2010). Birds in urban ecosystems: population dynamics, community structure, biodiversity, and conservation. Urban Ecosystem Ecology. Pp. 75-86. In Urban Ecosystem Ecology (J. Aitkenhead-Peterson and A. Volder, eds.), Agronomy Mongraphs 55. American Society of Agronomy, Inc., Crop Science Society of America, Inc., Soil Science Society of America.

Shwartz, A., Turbé, A., Simon, L., & Julliard, R. (2014). Enhancing urban biodiversity and its influence on city-dwellers: An experiment. *Biological Conservation, 171*, 82–90.

Sikes, R. S., & Animal Care and Use Committee of the American Society of Mammalogists. (2016). Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education. *Journal of Mammalogy, 97*(3), 663–688.

Sol, D., González-Lagos, C., Moreira, D., Maspons, J., & Lapiedra, O. (2014). Urbanisation tolerance and the loss of avian diversity. *Ecology Letters, 17*(8), 942–950.

Sushinsky, J. R., Rhodes, J. R., Possingham, H. P., Gill, T. K., & Fuller, R. A. (2013). How should we grow cities to minimize their biodiversity impacts? *Global Change Biology, 19*(2), 401–410.

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.

Ulmer, J. M., Wolf, K. L., Backman, D. R., Tretheway, R. L., Blain, C. J., O'Neil-Dunne, J. P., & Frank, L. D. (2016). Multiple health benefits of urban tree canopy: The mounting evidence for a green prescription. *Health & Place, 42*, 54–62.

United Nations, Department of Economic and Social Affairs, Population Division (2015). World urbanization prospects: The 2014 revision, (ST/ESA/SER.A/366). https://esa.un.org/unpd/wup/publications/files/wup2014-report.pdf

Vakhlamova, T., Rusterholz, H.-P., Kanibolotskaya, Y., & Baur, B. (2014). Changes in plant diversity along an urban–rural gradient in an expanding city in Kazakhstan, Western Siberia. *Landscape and Urban Planning, 132*, 111–120.

Wilson, D. E., & Reeder, D. M. (2005). *Mammal species of the world: a taxonomic and geographic reference (3rd Ed.). 2 Volumes*. Baltimore: Johns Hopkins University Press.

Wolch, J. R., Byrne, J., & Newell, J. P. (2014). Urban green space, public health, and environmental justice: the challenge of making cities 'just green enough'. *Landscape and Urban Planning, 125*, 234–244.

Yang, J., McBride, J., Zhou, J., & Sun, Z. (2005). The urban forest in Beijing and its role in air pollution reduction. *Urban Forestry & Urban Greening, 3*(2), 65–78.