Small mammal community composition and species diversity in the Shai Hills Resource reserve, Ghana

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Abstract

Biodiversity monitoring and assessment are essential for establishing population trends and status, and the causes of declines in abundance and occupancy within protected areas. However, biodiversity monitoring and assessment are rarely done in developing countries because of funding and other logistic constraints. This study assessed the small mammal (rodents and shrews ≤ 200 g) species composition and diversity in the Shai Hills Resource reserve with the aim of establishing baseline data for regular monitoring. The small mammals were live-trapped using Sherman and Pitfall traps. A trapping effort of 1,080 Sherman trap-nights and 360 Pitfall trap-nights yielded 36 individuals belonging to two orders (Rodentia and Eulipotyphla) and nine species. Five new species, including two shrews *Crocidura olivieri* and *C. crossei*, and three rodents *Mus musculoides*, *Mastomys natalensis* and *Arvicanthis rufinus* were added to the known small mammal species in the reserve. *Uranomys ruddi* was the most abundant species. All the species that were captured are listed as 'Least Concern' on the IUCN Red List of Threatened Species and are under no form of protection nationally. The results of this study provide crucial baseline data to the park managers to monitor the population dynamics and changes in the community composition of small mammal in the SHRR and evaluate the impact of management actions on the small mammal biodiversity in the reserve. This can improve their understanding of conservation needs and guide the development of effective habitat management strategy.

Key words: Accra Plains, biodiversity monitoring, conservation planning, protected areas, rodents, shrews

Introduction

Protected areas (PAs), remain crucial for safeguarding global biodiversity (Geldmann et al., 2013; Watson et al., 2014; Stienke et al., 2018). However, for PAs to be managed effectively so as to sustain biodiversity in perpetuity, knowledge of the species they harbor, conservation status of the species, and population trends is critical (Chettri, et al., 2008). Consequently, biodiversity assessment and monitoring has become an essential tool for the effective management of PAs (Pellissier et al., 2020; Kamp et al., 2021). Indeed, monitoring and assessment of occupancy and distribution of wildlife in PAs is important to guide species management and set conservation priorities (Suárez-Tangil and Rodríguez, 2021). For this reason, the need for biodiversity assessment and monitoring at all levels is recognized by international treaties such as the Convention on Biological Diversity (CBD), the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), the Convention on the Conservation of Migratory Species, the European Union (EU), and the Intergovernmental Panel on Biodiversity and Ecosystem Services (IPBES) among others (Larigauderie & Mooney, 2010; Granjou et al., 2013).

The Shai Hills Resource reserve (SHRR) is a very important protected area in the heart of the rapidly urbanizing Accra Plains of Ghana. The primary management objective of the reserve is to protect natural ecosystems, habitats and associated cultural values, and promote scientific research, recreation, appropriate small-scale tourism and sustainable use of the

natural resources (Andoh, 2019). The SHRR receives high patronage by both local and international tourists because of its proximity to the Central Business District (CBD) of Accra, the capital city of Ghana. The SHRR includes an extensive system of isolated inselbergs surrounded by open and wooded grassland (Dowsett-Lemaire and Dowsett, 2013). The reserve harbours several large mammal species including *Papio anubis* (olive baboons), *Chlorocebus* (*aethiops*) *tantalus* (Tantalus monkey), *Kobus kob* (kob), *Tragelaphus scriptus* (bushbuck) and *Philantomba maxwellii* (Maxwell's duiker). The deployment of camera traps in the SHRR recently confirmed the presence of *Leptailurus serval* (serval cat), *Nandinia binotata* (African palm civet) and *Civettictis civetta* (African civet). Although the diversity and distribution of large mammals in the SHRR is fairly known, there is scant information on the small mammals in the reserve.

Small mammals include a diverse group of species that play important ecological, economic and socio-cultural role in natural ecosystems (Brehm et al., 2019). They shape the structure and functioning of the ecosystem by influencing tree recruitment through their selective foraging on seeds and seedlings (Michal and Rafał, 2014), consuming large amount of insects and other invertebrates, and serving as prey for secondary consumers (Spencer et al., 2014). Within the SHRR, small mammals are an important food source for snakes, monitor lizards, owls and kites. Therefore, population fluctuations of small mammal communities in the reserve affect energy and nutrient transfer through the food web, ultimately affecting the overall energy and population dynamics of the SHRR ecosystem. Furthermore, small mammals are generally abundant, habitat specific and have limited dispersal abilities, rapid turnover and quick response to environmental changes, making them good bio-indicators (Avenant, 2011). Consequently, it is important to understand the species diversity, composition and population status of small mammals in the SHRR which is increasingly affected by expanding urbanization.

Little is however known about the small mammals in the SHRR; currently the community composition, population trends and conservation status of the small mammal species in the SHRR is unknown. To the best of our knowledge, there are only two published studies on the small mammals of the SHRR and these were conducted in the late 1950s (Booth, 1959) and early 1990s (Decher and Bahian, 1999). Decher and Bahian's (1999) study remains the most comprehensive study of the small mammals of the Accra Plain and SHRR. They reported the presence of Tatera kempi (now Gerbilliscus kempi), *Uranomys ruddi*, *Lemniscomys striatus*, *Graphiurus lorraineus* and *Praomys tullbergi* in SHRR. Although this study provided an important update of the small mammal species list for the reserve then, currently it is out of date and new studies are required to update the species list of the SHRR.

This study therefore aims at updating the small mammal species list of the reserve and to establish a baseline data for future monitoring and assessment. Specifically, we assessed small mammal species diversity, community composition, distribution, sex ratio, breeding condition and conservation status in SHRR. The data from this study can serve as inputs to update the existing management plan of SHRR for proactive conservation.

Materials and Methods

Study area

The Shai Hills Resource Reserve (SHRR; 5.85° - 5.97° N, 0.03810 - 0.0906° E) covers an area of about 49 km^2 and is the only fenced national reserve in Ghana (Dowsett-Lemaire and Dowsett, 2013). The reserve is located in the north-east sector of the Accra Plains (Siakwah, 2018) within the Shai Osudoku District of the Greater Accra region of Ghana (Fig. 1). The annual mean temperature of the area is between 25^{o}C and 28^{o}C and the annual mean precipitation is ~900 mm. The reserve is characterised by grassland with small thickets

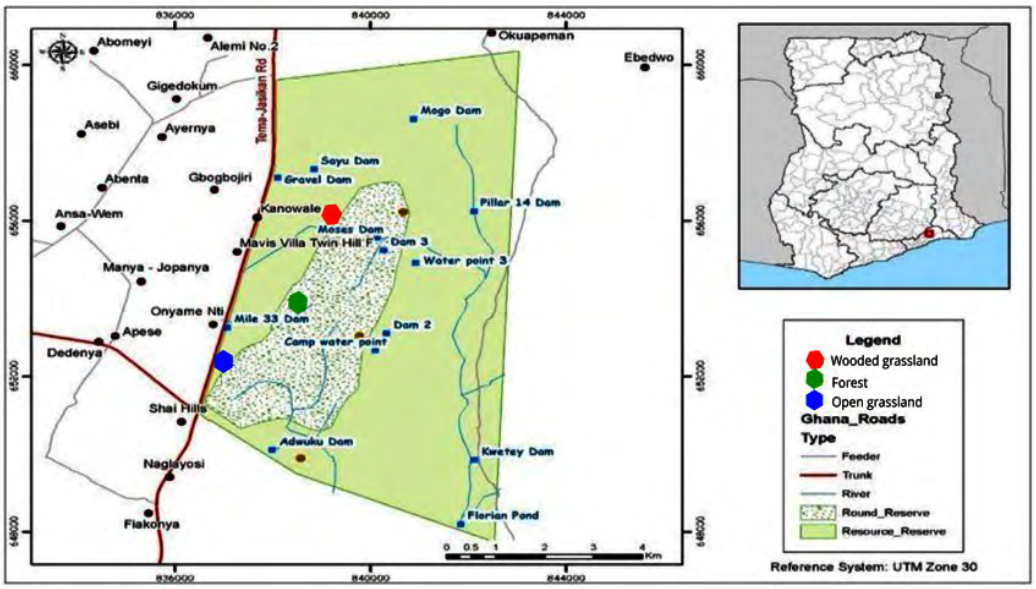

Fig. 1 Map of Shai Hills Resource Reserve showing the three sampling sites: Wooded grassland, Open grassland and Forest (sourced from Antwi et al., 2017)

often around eroded termitaria (Schmitt and Adu-Nsiah, 1993). The tree species in the reserve include *Adansonia digitata* (baobab), *Millettia thonningii* (Turburku fruit), *Combretum fragrans* (four-leaved combretum), *Vitex doniana* (black plum), *Ficus platyphylla* (gutta percha), *Ficus carica* (fig), *Azadirachta indica* (neem), *Diospyrus abyssinica* (giant diospyros), *Zanthoxylum xanthoxyloides* (Senegal prickly-ash), *Grewia* sp. (Phalsa), *Carissa edulis* (climbing num-num), *Lonchocarpus sericeus* (lancepod), and *Pterocarpus erinaceus* (African kino). The grassland mostly comprises *Vetiveria fulvibarbis* (Vertiver grass), *Brachiaria falcifera* (Stapf), *Andropogon canaliculatus* (broomsedge), and *Fimbristilis ovata* (flatspike sedge) (Decher and Bahian, 1999).

Sampling site selection

Three sites were selected to represent the different vegetation types in the Shai Hills Resource reserve: Open grassland (N05.89736° E0. 04618°), Wooded grassland (N05.87509° E0.05197°) and Forest (N5.90161111° E0.05327778°, Fig. 2). The open grassland is characterized by short grasses with small thickets of neem trees often

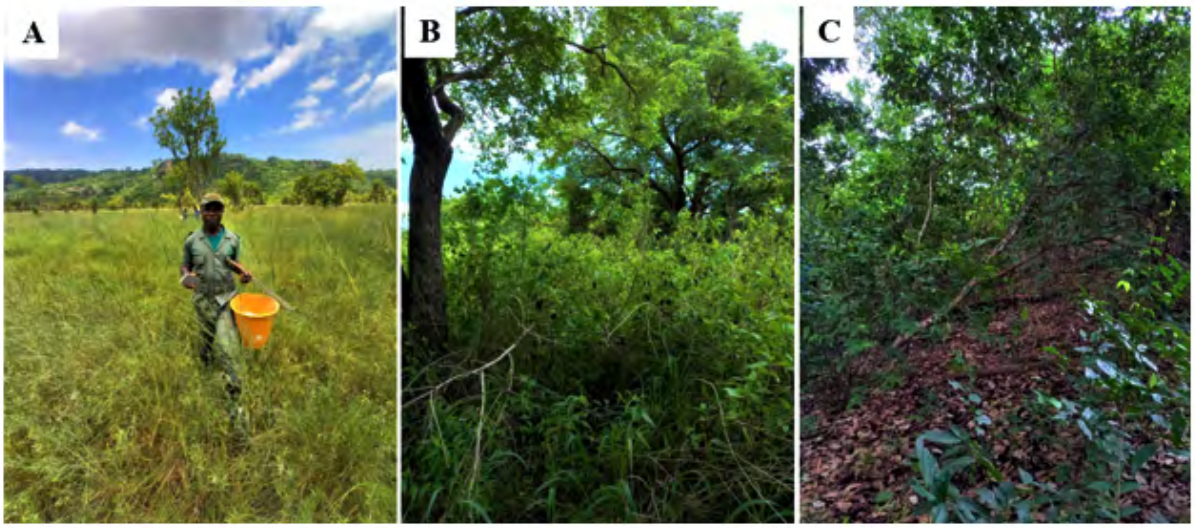

Fig. 2 Vegetation types in which the small mammals were sampled (Open grassland (A), Wooded grassland (B), and Forest (C))

around eroded termitaria. This grassland is burnt annually (controlled early burning) by the reserve management. The dominant grasses include A*ndropogon canaliculatus Vetiveria fulvibarbis*, and *Brachiaria falcifera*, and the trees include *Azadirachta indica*, *Combretum fragrans*, and *Lonchocarpus sericeus*.

The wooded grassland is a mosaic of short and tall grasses, and shrubs with a high density of trees. The dominant tree species were *Azadirachta indica*, *Ficus* sp, *Zanthoxylum xanthoxyloides*, *Combretum fragrans Grewia* sp., *Carissa edulis*. This area is not burnt by the reserve management, but is burnt almost every year by accidental fires from human activities outside the boundaries of the reserve. The forest is located on the hills with rocky outcrop and in the valleys where there is no rocky outcrop. The neem tree has not invaded this area. The common trees include *Adansonia digitata*, *Millettia thonningii*, *Diospyrus abyssinica*, *Ceiba pentandra* and *Ficus carica.*

Live trapping of small mammals

Approval was sought from the University of Ghana College of Basic and Applied Sciences Animal Care and Research Ethics Committee (Ref. No. ECBAS 024/18-19). Live-trapping and handling protocols followed guidelines of the American Society of Mammalogists (Sikes and Mammalogists, 2016). The small mammals were captured using standard Sherman live-traps (23 cm x 9 cm x 7.5 cm, H.B. Sherman Traps Inc., Florida, USA) during the rainy season in the open grassland, wooded grassland and forest. In each vegetation type two line transects, each of about 150 m, were established. Fifteen traps were set on the ground along each transect; one trap placed per trap station, with inter-trap distance of 10 m. In the forest, some traps were placed on fallen logs and in tree branches to enhance the capture of arboreal species. Traps were baited with peanut butter mixed with crushed maize. Traps were set in the late afternoon (17.00 hours GMT) and were checked the following morning between 7.00 and 9.00 hours GMT for three consecutive nights in four trapping sessions, with one trapping session in May, June, July and September 2021. Additionally, one pitfall trap-line with drift fence installed was established in the open grassland and wooded grassland. Pitfall traps could not be set in the forest because the ground was rocky and difficult to dig. The pitfall traps consisted of 15 buckets (rim diameter = 320 cm, base diameter = 220 cm, height = 330 cm) buried along a line transect, with inter-bucket distance of about five meters. Like the Sherman traps, pitfall traps were set for three consecutive nights during each of the four trapping sessions. There were therefore a total of 1,080 Sherman trap-nights and 360 Pitfall trap-nights.

Trapped animals were transferred into transparent plastic bags and weighed using a Pesola spring balance. For the purpose of identification, external body measurements including head and body length, tail length, hindfoot length, and ear lengths were taken with a digital caliper. The sex and breeding condition of the animals were also recorded. Captured animals were marked by toe-clipping and released at the site of capture. The identification of small mammals followed Hutterer & Happold (1983), Happold (2013), Monadjem et al. (2015) and Wilson et al. (2017). The taxonomy of small mammals followed Wilson et al. (2017) and conservation status was based on the updated IUCN Red List of Threatened Species (2020), available at www.redlist.org.

Data Analysis

Species richness (S) was estimated as the total number of species captured at the site. Chao1, Chao2, Jacknife1 and Bootstraps was used to estimate the potential species richness in the reserve. Relative abundance (%) was estimated as the ratio of the number of individuals of a particular species to the total number of individuals of all the species captured at a site multiplied by 100%. The trap success was estimated as the number of individuals captured per 100 trap-nights (where a trap-night equals one trap set for one night). The Sorensen's similarity index

was used to compare the species composition among the different vegetation types, and Shannon's (**H'**) and Pielou's (**J'**) indices were used to calculate the species diversity and evenness, respectively, as follows:

$$\mathbf{H'} = \sum_{i=1}^{R} pi \ln pi$$

$$\mathbf{J'} = {}^{H'}/_{\mathrm{Log}(\mathbf{s})}$$

where *pi* is the proportion of species i in the community and **S** is the species richness. All the analyses were done using the Primer 6 software (Version 6.1.13).

Results

Species richness, diversity and composition

In total, 36 individuals belonging to two orders (Rodentia and Eulipotyphla) and nine species were captured, with high evenness of species (i.e., the individuals were uniformly distributed across the nine species). The overall diversity (H') and evenness (J') were 1.8605 and 0.8467, respectively, for the SHRR. The rodents were *Uranomys ruddi* (White-bellied brush-furred rat), *Mus musculoides* (Temminck's mouse), *Arvicanthis rufinus* (African grass rat), *Mastomys natalensis* (Natal's multimammate rat), *Gerbilliscus kempi* (Kemp's gerbil), *Lemniscomys striatus* (Typical grass striped rat) and *Praomys tullbergi* (Tullberg's soft-furred rat), while the shrews were *Crocidura olivieri* (African giant shrew) and *Crocidura crossei* (Crosse's shrew). The species richness curve did not reach an asymptote (Fig. 3-6) and the species richness estimators suggested a higher value than what was observed (Chao1 = 9, Chao2 = 11, Jacknife1 = 12, Jacknife2 = 13; Bootstrap = 10).

Uranomys ruddi was the dominant species in the reserve, followed by *G. kempi* and *M. musculoides*. These three species together

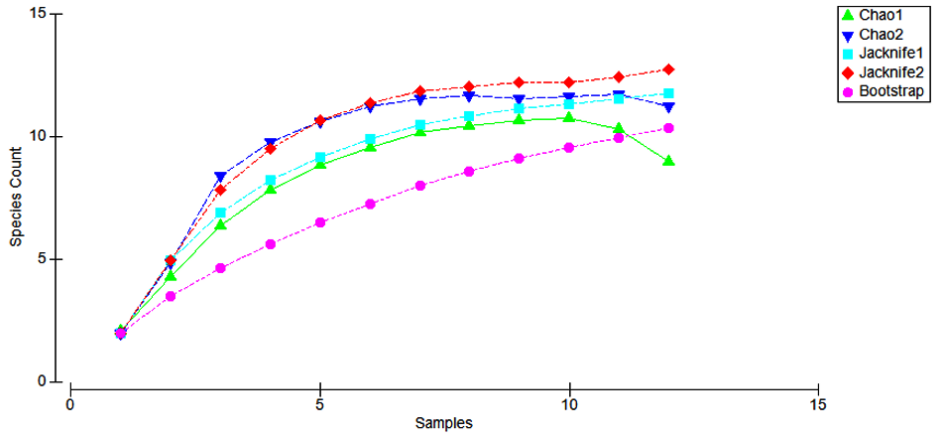

Fig. 3 Overall small mammal species richness curve for the Shai Hills Resource reserve

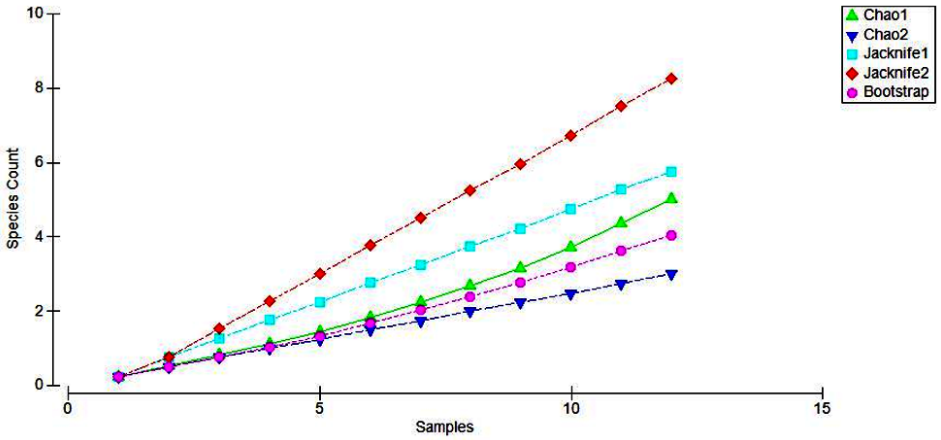

Fig. 4 Small mammal species richness curve for the open grassland in the Shai Hills Resource reserve

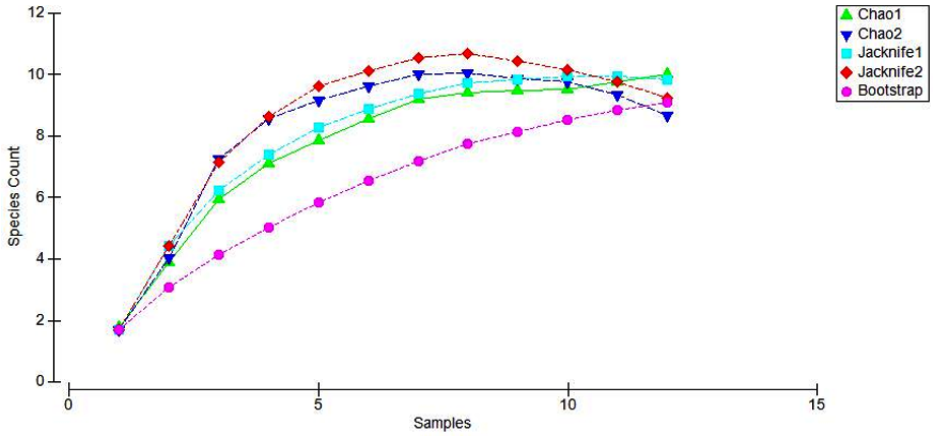

Fig. 5 Small mammal species richness curve for the wooded grassland in the Shai Hills Resource reserve

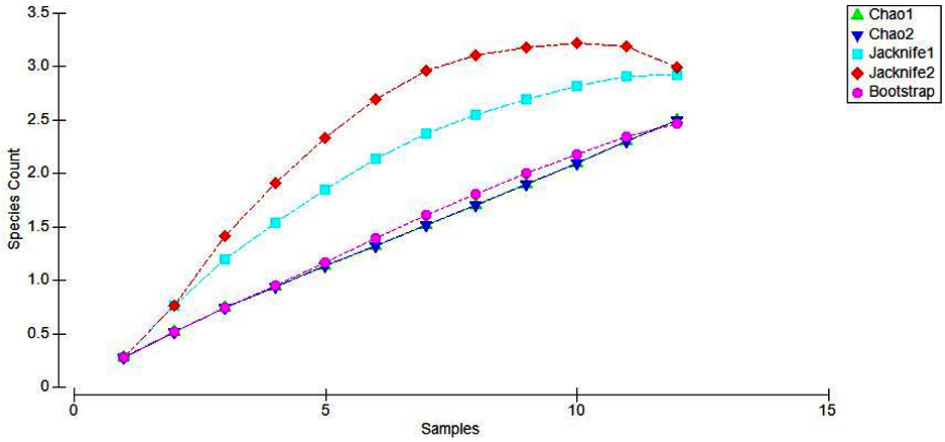

Fig.6 Small mammal species richness curve for the forest in the Shai Hills Resource reserve

TABLE 1

Abundance, diversity and composition of small mammals at Shai Hills Resource reserve. The percentage of the ith species (relative abundance) is shown in brackets

Species	Open grassland	Wooded grassland	Forest	Total (present study)
Arvicanthis rufinus	0 (0)	3 (10)	0 (0)	3 (8)
Uranomys ruddi	1 (25)	10 (34)	2 (67)	13(36)
Mus musculoides	2 (50)	3 (10)	0 (0)	5(14)
Mastomys natalensis	0 (0)	1 (3)	0 (0)	1(3)
Lemniscomys striatus	1 (25)	2 (7)	0 (0)	3(8)
Praomys tullbergi	0 (0)	0 (0)	1 (33)	1(3)
Gerbilliscus kempi	0 (0)	6 (21)	0 (0)	6(17)
Graphiurus lorraineus	0 (0)	0 (0)	0 (0)	0 (0)
Crocidura olivieri	0 (0)	1 (3)	0 (0)	1(3)
Crocidura crossei	0 (0)	3 (10)	0 (0)	3(8)
Number of individuals	4	29	4	36
Number of species	3	8	2	9
Shannon's index (H')	1.04	1.814	0.637	1.861
Pielou's index (J')	0.946	0.872	0.918	0.847

formed 67% of the total captures (Table 1). The overall trap success was comparable between the Sherman and pitfall traps; Sherman trap effort of 1080 trap-nights yielded 26 individuals, giving a trap success of 2.5%, whereas pitfall trap effort of 360 trap-nights yielded nine individuals, also giving a trap success of 2.5%. All the individuals of shrews (4) and *M. musculoides* (5) were captured by the pitfall traps, and the rest by Sherman traps. The wooded grassland had the highest species richness and diversity followed by the open grassland and the forest (Table 1). The species richness curves for the forest, wooded grassland and open grassland did not reach a plateau (Fig. 4-6) and the total species richness at these sites were estimated to be slightly higher than the observed value (wooded grassland: Chao1 = 10, Chao2 = 9, Jacknife1 = 10, Jacknife2 = 9, Bootstrap = 9; open grassland: Chao1 = 5, Chao2 = 3, Jacknife1 = 6, Jacknife2 = 8, Bootstrap = 4; forest: Chao1 = 3, Chao2 = 3, Jacknife1 = 3, Jacknife2 = 3, Bootstrap = 2).

Distribution, habitat association and conservation status

Praomys tullbergi was captured in the forest habitat only, while *Uranomys ruddi* was captured in the wooded grassland, open grassland and the forest edge. *Mus musculoides* was captured in the wooded and open grassland, but not the forest. *Lemniscomys striatus* was captured in the open and wooded grassland, while *A. rufinus*, *G. kempi M. natalensis*, *Crocidura crossei* and *Crocidura olivieri* were captured in the wooded grassland only. All the small mammals captured at SHRR are listed as 'Least Concern' (LC) on the IUCN Red List of Threatened species and are under no form of national protection in Ghana (Table 3). *Praomys tullbergi* is endemic to the Upper Guinean Forest Block, but are common and widespread within its distribution range and in Ghana.

Sex ratio and breeding condition of small mammals

In general, more male individuals were captured than females, but *G. kempi* had more females (4) than males (2). Ten of the 13 individuals of *U. ruddi* were males, while all the *M. musculoides* and *A. niloticus* individuals were males. The single individuals of *M. natalensis* and *P. tullbergi* were also males (Table 3). The sex of the shrews was difficult to determine with live specimens, but most (75%) of the adult rodents showed signs of breeding activity (scrotal testes in males as well as perforate vagina and enlarged mammae in females).

TABLE 2

Conservation status, sex ratio and breeding condition of small mammals captured at the Shai Hills Resource reserve (LC = Least Concerned)

Species	Common name	IUCN status	Male (M)	Female (F)	No. in breeding condition
Praomys tullbergi	Tullberg's soft-furred rat	LC	1	-	1
Uranomys ruddi	White-bellied brush-furred rat	LC	10	3	9 (6 M, 3 F)
Mus musculoides	Temminck's mouse	LC	5	-	3
Arvicanthis nicoticus	African grass rat	LC	3	-	2
Mastomys natalensis	Natal's multimammate rat	LC	1	-	1
Gerbilliscus kempi	Kemp's gerbil	LC	2	4	6 (2M 4 F)
Lemniscomys striatus	Typical grass striped mouse	LC	2	1	2 (all M)
Crocidura olivieri	Olivier's shrew	LC	-	-	-
Crocidura crossei	Crosse's shrew	LC	-	-	-

Discussion

Small mammal species diversity and community composition was assessed for the first time in 30 years at the SHRR in Accra, Ghana with the aim of updating the species list of the reserve and to provide baseline data for regular monitoring of small mammals in the reserve. The last published document on the small mammal in SHRR by Decher and Bahian (1999) yielded 27 individuals of five rodent species included *Graphiurus lorraineus*, *Lemniscomys striatus*, *Praomys tullbergi*, *Gerbilliscus kempi* and *Uranomys ruddi*, in 3,600 Sherman trap-nights. In this study, nine species comprising seven rodent species and two shrew species were recorded. Five species, including three rodent species, *Mus musculoides*, *Arvicanthis rufinus*, and *Mastomys natalensis*, and two shrew species, *Crocidura olivieri* and *C. crossei* that were captured in this study were not recorded in Decher and Bahian 's (1999) in 1991/1992. However, the rodent species *Graphiurus lorraineus* that was recorded in the previous study was not captured in this study. The updated species list for the SHRR now stands 10 species comprising eight rodent and two shrew species.

The species richness estimators indicated that the small mammal species in SHRR has risen from 9 to 13, which means that 69.2-100% of the species potentially present in SHRR were captured. Some species may have probably been missed due partly to the low trapping effort and the types of traps used in the study. Studies show that detection probability differs among species and even for individuals of the same species based on sex, age, body condition and behaviour, and that the types of traps used influence the capture of small mammals (Graipel et al., 2003; Nicolas and Colyn, 2006; Umetsu et al., 2006; Torre et al., 2011; Santos-Filho et al. 2015; Harkins et al., 2019). For instance, Santos-Filho et al. (2015) showed variations of species sampled using pitfall, Sherman and tomahawk traps, with pitfall traps capturing a more distinct subset of the small mammal community than the two other live traps. In a study comparing the performance of Longworth, Sherman, and Ugglan small mammal live-traps in Nearctic boreal forests, Jung (2016) found that Sherman traps captured significantly fewer species than did either Longworth or Ugglan traps. Therefore, different trap types complement each other (Nicolas and Colyn, 2006; Torre et al., 2011; Jung, 2016; Harkins et al., 2019). Indeed, this study would have benefitted from the inclusion of Tomahawk traps, which are more effective for capturing larger-sized rodents like the giant-pouched rat (*Cricetomys gambianus*) and squirrels, such as the Gambian sun squirrel and the Striped ground squirrel. At the time of this study, no Tomahawk traps were available and therefore such traps were not employed.

In accordance with many studies (e.g., Nicolas and Colyn, 2006), the species composition varied between pitfall traps and Sherman traps, with the former being more efficient than the latter in the capture of shrews and small-sized rodents such as *M. musculoides*. The Sherman traps however captured a more diverse small mammal species than the Pitfall traps. Decher and Bahian (1999) did not include pitfall traps in their survey at SHRR and this may be the reason why they did not capture any shrews and the small-sized rodent *M. musculoides*. These species were exclusively captured by pitfall traps in this study.

The record of nine species captured at SHRR is comparable to that obtained for some of the other green areas within the Accra Plains of Ghana. For example, a study of the small mammal community in the University of Ghana botanical garden (Ofori et al., 2018) and Achimota forest reported 10 and eight species, respectively. The species richness at SHRR is also comparable to the 10 species recorded at the Muni-Pomadze Ramsar Site (Ofori et al., 2016), a coastal wetland in the Central region of Ghana. Like the SHRR, the University of Ghana botanical garden, Achimota forest and Muni-Pomadze Ramsar Site are all mosaics of grassland, thicket and forest.

More males were captured than females and also more individuals showing signs

of breeding activity. Many small mammal surveys recorded higher capture frequency of males than females and individuals in breeding condition particularly during the wet season (Innes and Bendell, 1988; Attuquayefio and Wuver, 2003; Nicolas and Colyn, 2003; Sánchez-Chardi and Nadal, 2007; Fichet-Calvet et al., 2009). This is probably because of an abundance of protein-rich diets like foliage, seedlings and insects and lush vegetation cover during the wet season that provide sufficient security for lactating females and their offspring (Habtamu and Bekele, 2013; Ofori et al., 2016). Dispersal of rodents is generally male-biased, as indicated by males encountering traps more frequently than females (Nicolas and Colyn, 2003).

Praomys tullbergi is a forest specialist species that is able to tolerate some degree of forest degradation and was captured in the forest habitat only. It also can be found in secondary forests, wooded vegetation and agroforestry landscapes. Booth (1959) described this species from the Accra Plains as "a forest species confined to the sub-scarp zone and riparian forest". *Uranomys ruddi* was captured in the wooded grassland, open grassland and along the edges of the forest. This species prefers grassland and shrubland. Mus musculoides was captured in the wooded and open grassland, but not the forest. This species is a habitat generalist that inhabits all vegetation types including farmland. *Arvicanthis rufinus*, *Lemniscomys striatus*, *Gerbilliscus* (*Tatera*) *kempi* and *Mastomys natalensis* are typical dry savanna grassland/ woodland and shrubland species. *Mastomys natalensis* is an opportunistic species that invades farms and forest edges abutting farmlands. *Mastomys* species were captured by Decher and Bahian (1999) only from the more agricultural area near Kpong on the Accra Plains. The increasing urban sprawl of the Accra Plains around the Shai Hills might have led to the spread of this more commensal genus into SHRR. *Lemniscomys striatus* was captured in both the open and wooded grassland, but *A. nicoticus*, *G. kempi* and *M. natalensis* were captured in the wooded grassland only. *Crocidura olivieri* also was captured in the wooded grassland. This species is a habitat generalist that occurs in savanna, farmland, openings in the forest and other human modified landscape. *Crocidura crossei* has an affinity for lowland forest, but the species also occurs in wooded vegetation. This species was recorded in the wooded grassland at the SHRR.

The abundance and distribution of small mammals vary spatio-temporally depending on the structural complexity of the vegetation cover and availability and distribution of valuable resources (Blaum et al., 2007), as well as the extent to which individuals can tolerate biotic (e.g. competition and predation) and abiotic (e.g. climate) conditions (Avenant, 2011). Some species are often present in high numbers because they are able to maximize the available resources (Magurran and Henderson, 2003). However, if conditions in an ecosystem change sufficiently in favour of other species, it may lead to a shift in the dominant (most abundant) species. In their study, Decher and Bahian (1999), recorded *Lemniscomys striatus* as the most abundant species in open/ wooded grassland, while *Praomys tullbergi* was the dominant species in the west slope habitat mosaic of thicket and grass with rocky outcrops, an area that forms part of the forest. However, in the present study *Uranomys ruddi* was the dominant species in the open/wooded grassland, whereas only one individual of *P. tullbergi* was captured in the forest with rocky outcrops.

Conclusion

Small mammal monitoring and assessment are essential for establishing population trends and status, and are crucial for guiding the development of effective conservation and management strategy. This study recorded 36 individuals of nine species, with high evenness of species and *Uranomys ruddi* being the most abundant species. Five new species, including two shrews *Crocidura olivieri* and *C. crossei*, and three rodents *Mus musculoides*, *Mastomys*

natalensis and *Arvicanthis rufinus* were added to the known small mammal species list in the SHRR. Although this study and the previous study done by Decher and Bahian (1997) are not comparable because of the different trapping protocols, some general observations regarding the community composition could be made. There appears to be a change in the small mammal community composition, which is mostly due to the addition of new species to the small mammal community in the reserve. However, the observed differences may be an artefact of sampling, given that Pitfall traps were employed in the present study but not in the previous study, and also because small mammals were not trapped at the exact sampling locations between the two studies. The observed change could also mean that the species that were captured in the present study did not occur in SHRR at the time of Decher and Bahian's study. On the whole, this study has provided data that can serve as baseline for future monitoring. The results of this study also provide crucial information for the park managers to evaluate the impact of management actions on the small mammal biodiversity in the park. This can provide a better understanding of the conservation needs and guide the development of efficient habitat management strategy.

The invasive neem trees in the reserve have currently increased to cover a greater portion of the reserve. During the data collection, cattle were seen grazing within the reserve. Also, instead of the normal controlled burning during the dry season as a management strategy, accidental burning of the grassland and thickets has become rampant in recent years due to human activities along the boundaries of the reserve. Given that these activities may affect the small mammals and other wildlife in the reserve, it is recommended that the management of the reserve take appropriate steps to combat cattle intrusions and grazing in the reserve. Also, management should regularly engage with the surrounding community members to harvest the neem trees in the reserve. The local people can get income from selling the wood and this may provide an incentive for them to support the conservation of the reserve. It is also recommended that conservation education and awareness programme should be promoted in the communities surrounding the SHRR.

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Data Availability

All data have been included in the manuscript except the measurements of the individuals captured. This data will be made available upon reasonable request.

Declarations

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Conflict of interests/Competing interests

The authors have no financial or competing interests to declare that are relevant to the content of this article.

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