Received: 5 June 2021 | Revised: 5 December 2022 | Accepted: 29 December 2022

DOI: 10.1111/aje.13111

RESEARCH ARTICLE

African Journal of Ecology WILEY

Examining the abundance and habitat use of golden-rumped sengi (*Rhynchocyon chrysopygus*) in Arabuko-Sokoke Forest in Kenya

Rael Nelly Nyanchama Ondoro[1] | **Benards Okeyo**[1] | **Colin Jackson**[2]

[1]Department of Environmental Sciences, Pwani University, Kilifi, Kenya

[2]A Rocha Kenya, Watamu, Kenya

Correspondence
Rael Nelly Nyanchama Ondoro, Department of Environmental Sciences, Pwani University, PO Box 195-80108, Kilifi, Kenya.
Email: raelnelly@gmail.com

Funding information
Nature Kenya; The Mohammed Bin Zayed Species Conservation Fund

Abstract

The International Union for Conservation of Nature (IUCN) classifies the golden-rumped sengi (*Rhynchocyon chrysopygus*) as an 'endangered' species'. They are endemic to fragmented forests in eastern Kenya. Existing evidence indicates a decline in their population in Arabuko-Sokoke Forest; however, these studies were conducted over a decade ago. This study assessed their abundance in three vegetation types. This study was conducted in the months of September, October and November in the year 2019. We used line transects in the forest types to locate nests and recorded the distances to the nests together with habitat variable measurements. We used (10 by 10 m) quadrats to obtain data on deadwood. We used line transect distance sampling to estimate sengi density and abundance. We employed linear regression models to examine the association between the number of nests per transect and deadwood volume, while means and proportions were used to examine the determinants of sengi nesting sites. The golden-rumped sengi population was estimated to be 19,423. Besides, deadwood volume was not associated with nest site occurrence. Although findings from this study indicate an increase in the golden-rumped sengi population from 12,750 individuals in 2009, continued monitoring is essential to inform conservation measures.

KEYWORDS
abundance, Arabuko-Sokoke Forest, golden-rumped sengi, Kenya, *Rhynchocyon chrysopygus*, small mammals

Résumé

L'Union Internationale pour la Conservation de la Nature (UICN) classe le sengi à croupion doré (*Rhynchocyon chrysopygus*) comme une espèce « en voie de disparition ». Ils sont endémiques aux forêts fragmentées de l'est du Kenya. Les preuves existantes indiquent un déclin de leur population dans la Forêt d'Arabuko-Sokoke ; cependant, ces études ont été menées il y a plus d'une décennie. Cette étude a évalué leur abondance dans trois types de végétation. Cette étude a été menée au cours des mois de septembre, octobre et novembre de l'année 2019. Nous avons utilisé des transects linéaires dans les types de forêts pour localiser les nids et enregistré les distances par rapport aux nids avec les mesures des variables d'habitat. Nous avons utilisé des quadrats (10 sur 10 m) pour obtenir des données sur le bois mort. Nous avons utilisé un échantillonnage de distance par transect linéaire pour estimer la densité et l'abondance des sengis. Nous avons utilisé des modèles de régression linéaire pour examiner l'association entre le nombre de nids par transect et le volume de bois mort, tandis que les moyennes et les proportions ont été utilisées pour examiner les déterminants des sites de nidification des sengis. La population de sengis à croupion doré était estimée à 19 423. De plus, le volume de bois mort n'était pas associé à la présence de sites de nids. Même si les résultats de cette étude indiquent une augmentation de la population de sengis à croupion doré de 12 750 individus en 2009, une surveillance continue est essentielle pour éclairer les mesures de conservation.

1 | INTRODUCTION

One of the greatest modern-day threats to terrestrial species worldwide is habitat change which includes habitat loss, habitat fragmentation and habitat degradation (Bellard et al., 2014). Human impacts are a major contributor to the destruction of wild habitats, and therefore responsible for the loss of genetic diversity within and among species and in extreme cases species extinction (Lusweti, 2011).

The golden-rumped sengi (*Rhynchocyon chrysopygus*) is among the giant sengis which are members of the family Macroscelididae (Smit, 2008). They can be differentiated from other sengi species because of their dark amber colour with black legs and feet and a bright yellow rump patch with slightly longer hair (Rovero et al., 2008). They are diurnal and feed only on insects in deep leaf litter and soil, thus their preference to live in forests. Forests with closed-canopy woodlands and thickets with a floor that is densely covered by leaf litter provide the ideal habitat for this sengi (Rovero et al., 2013). They use their long nose as a probe to search for prey, while their long tongue is used to flick food items into their mouths (Rathbun, 2009). The golden-rumped sengi has a limited range distribution in coastal forests of Kenya. Existing evidence shows that 90% of the known global population are found in Arabuko-Sokoke Forest (ASF) (Wekesa, 2017). Analyses from previous studies reveal a declining trend in this sengi's population in ASF (Ngaruiya, 2009). Over the years, the forest classification in ASF has changed as a result of human disturbance (Habel et al., 2017). The decline in the sengi population was attributed to the change in the forest quality resulting from forest degradation.

A study on the use and governance of ASF, listed firewood collection as the dominant forest-based economic activity, estimated at 40%. Although a 'formal exploitation' through Community Forest Association (CFA), firewood collection is gradually degrading the forest (Ndalilo et al., 2017). With the increased recognition of conserving flora and fauna, there is global prioritisation for monitoring species population. According to IUCN, the present status of the golden-rumped sengi in the forest habitats is unknown (with the last study having been done 13 years ago). The forest habitat and the sengi population continue to reduce because of the various anthropogenic factors identified in the past (FitzGibbon & Rathbun, 2014). Sengi nests were used as a proxy for golden-rumped sengi presence. Small mammals are often hard to see or find mainly due to their characteristics and behaviours, such as nocturnal activity patterns, camouflage and relative shyness (Cook, 2001). We aimed to determine a population estimate of the golden-rumped sengi in ASF. Additionally, there has not been any study to determine whether dead wood availability affects golden-rumped sengi nesting site choice and abundance. It was hypothesised that deadwood availability influenced the sengi abundance as they feed on insects which are generally in high abundance where deadwood volume is high. This study sought to address these gaps by examining the abundance of golden-rumped sengi across the three main habitat types in ASF and to establish whether the distribution of nesting sites was influenced by dead wood availability.

2 | METHODS

2.1 | Study area

Arabuko-Sokoke Forest is located in the coastal region of Kenya in Kilifi County. It traverses Kilifi North and Malindi subcounties at a latitude of 3°20′S and longitude 39°50′E. The forest covers an area that is approximately 41,600 ha (416 km^2) and is the largest single block of indigenous coastal forest remaining in East Africa. The forest has three main vegetation types: the mixed forest (70 km^2); *Brachystegia* forest (77 km^2) and *Cynometra* forest (235 km^2) (Arabuko-Sokoke Forest Management Team, 2002) (Figure 1).

We employed stratified random sampling method in this study because of the presence of different vegetation types in ASF. We laid 100 m line transects randomly in each of the three vegetation types following a random distance generation using the RANDBETWEEN function in Excel©. The number of transects made varied with the size of the study site. It is advisable to allocate effort in proportion to stratum size rather than assign great effort in high-density areas if the objective of the study includes relating animal density to habitat (Buckland et al., 2015). Consequently, nine transects were laid in mixed forest, 24 in *Cynomentra* forest and 11 in *Brachystegia* forest (Figure 2).

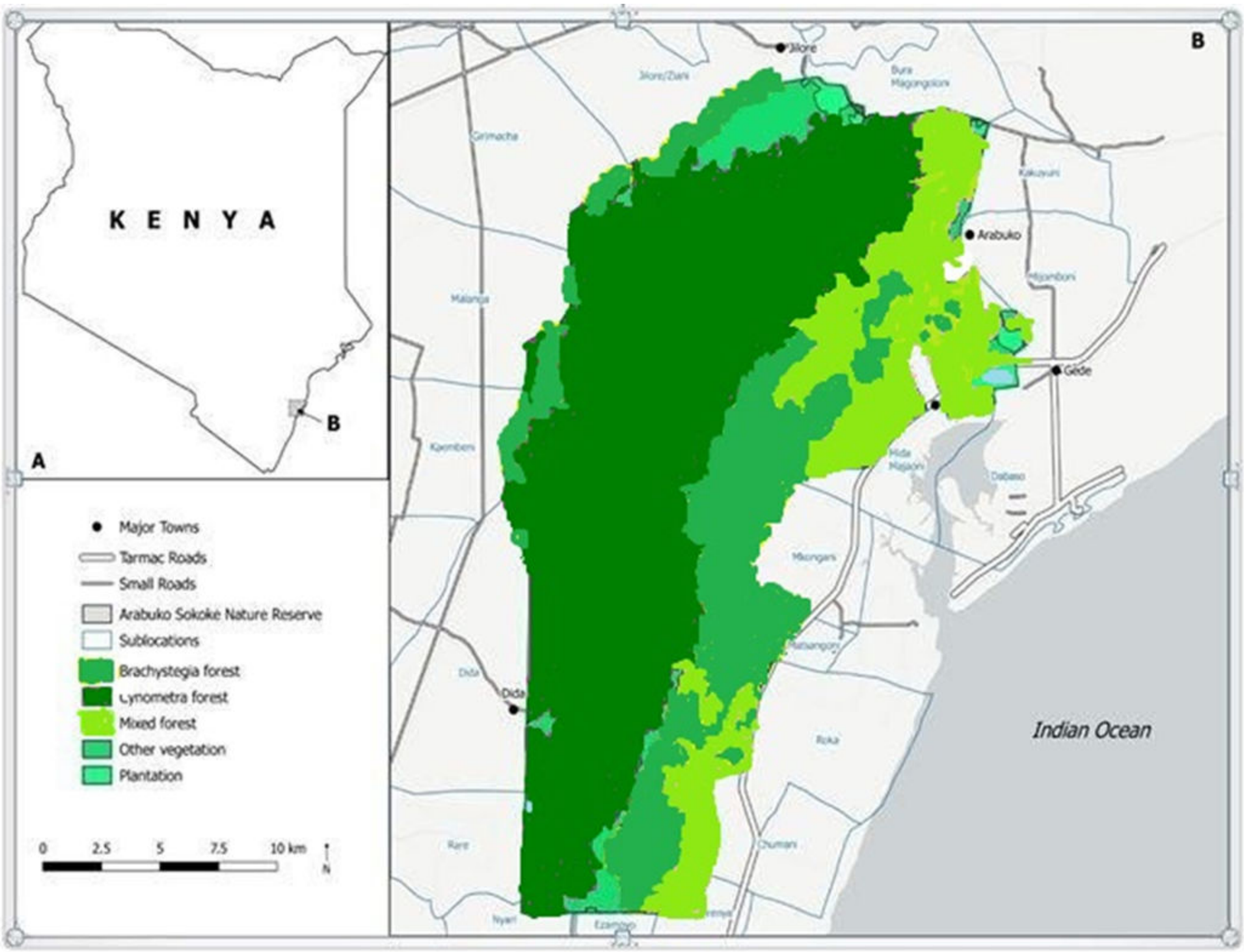

FIGURE 1 Location of Arabuko-Sokoke Forest and its vegetation types in Kenya.

We recorded the start and end location of each line transect using a global positioning system (GPS). A single observer walked once along a transect looking on both sides for sengi nests. The same observer was used throughout the study period to reduce observer bias and differences. Once a sengi nest was sighted, the perpendicular distance from the line transect to the nest was measured using a tape measure. GPS coordinates of the sengi nest were also recorded.

The assumptions that were considered for reliable estimation included that all nests directly on the transect were always detected, distances from the transect to the sengi nest were measured accurately, nests were identified correctly, and that nest's locations were independent of the positions of the transects (Fitzgibbon & Rathbun, 1994).

We used sample plots (10 by 10 m) at the centre of each transect to determine the amount of deadwood. We measured all pieces of deadwood in the plot with a minimum large-end diameter of 2 cm and length 20 cm using a tape measure (Eräjää et al., 2010). We recorded for each piece of deadwood; the degree of decay, diameter in the minimum section, diameter in the end section, and the length between the minimum and maximum sections (De Meo et al., 2017). We grouped the degree of decay into three classes. Class 1 included solid wood that likely had recently fallen, with an intact bark or bark that is starting to fall off. Class 2 included non-solid wood that was in poor condition in which a nail could be pushed into the wood by hand. Class 3 included soft, rotten wood which easily collapsed when stepped on (Baker & Chao, 2011).

Sengi nesting sites attributes that we examined in this study included the age of the nest, vegetation density, canopy cover, litter depth, canopy height, and the material composition of the nest. The age of the sengi nest was whether the nest was new or old. Heaped nests were classified as new, while nests that were flat or almost flat at the top were classified as old. We estimated the index of vegetation density using a checkerboard. The checkerboard was held at breast-height by the research assistant. The researcher then moved to four perpendicular points that were located 2 m from the nest and counted the number of boxes on the checkerboard that could be observed (were not covered by vegetation) to enable the calculation of the percentage of boxes covered. Canopy cover was also estimated at the four points where vegetation density was estimated by observing and estimating the percentage area of a circular tube of 4.5 cm diameter where the sky was not visible. For instance, if the

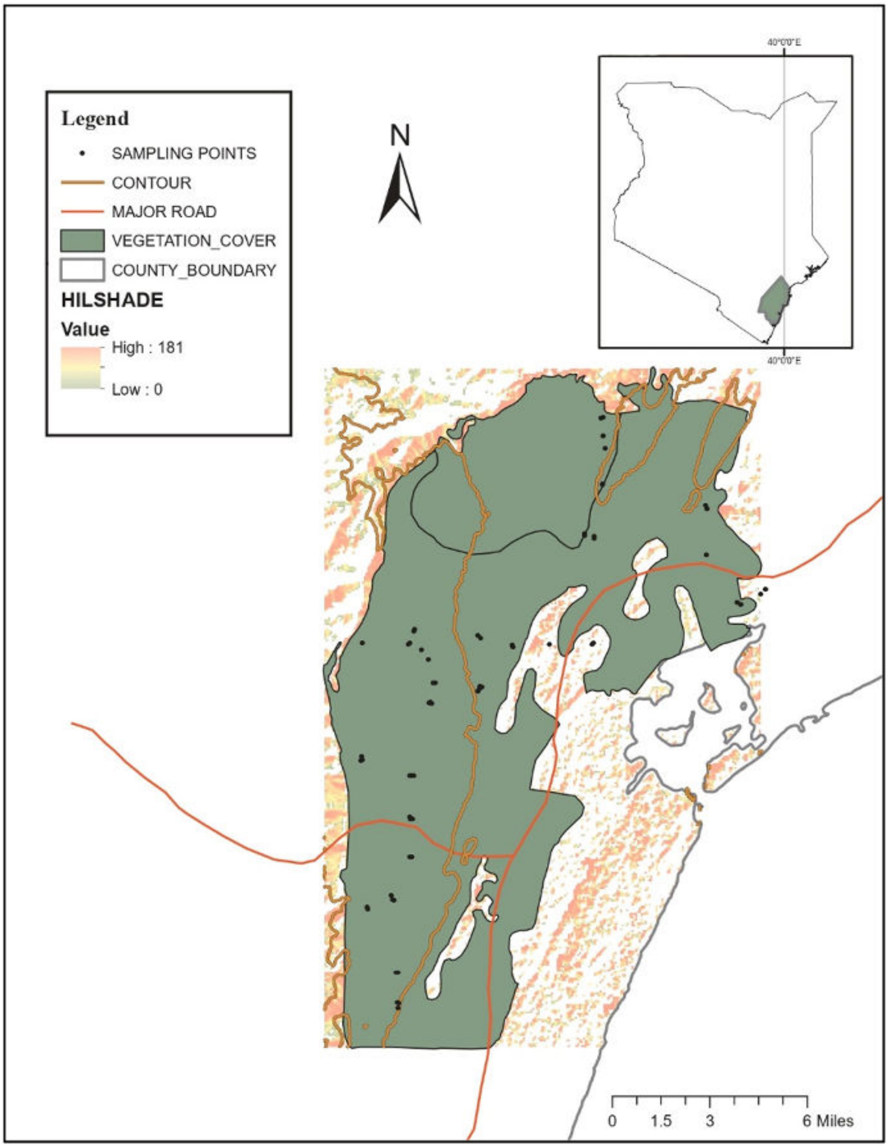

FIGURE 2 Transect location in the three vegetation types in Arabuko-Sokoke Forest.

sky was totally visible without any vegetation blockage, the canopy cover was estimated to be 0%.

Additionally, the level of litter depth was measured using a ruler 1 m from the nest. The choice of 1 m from the nest was to ensure that the litter was not part of the nest and, therefore, cause no disturbance to the nest. The canopy height at the nest was then determined by estimating the height of the nearest tallest tree covering the nest location. Last, we assessed the material composition of the nests by examining the distribution of the material compositions of nests categorised as leaves only or twigs only or leaves and twigs.

The perpendicular distances from the line transect to the sighted sengi nests (old and new) were used to model a detection function stratified by the vegetation type. Different detection functions for each vegetation type were estimated using the Distance program version 7.3 (Thomas et al., 2010) to calculate the golden-rumped sengi abundance. We estimated density and abundance using the following formulae in the multiple-covariate distance sampling (MCDS) engine in the Distance software (Buckland et al., 2004, 2015);

$$\hat{D} = \frac{n}{2L}.f(0)$$

where $\hat{D}$ is the density, n is the objects detected at perpendicular distances, $f(0)$ is the the probability density function at zero perpendicular distances and L is the length of the transect.

Multiple-covariate distance sampling detection function models were fitted by applying the half-normal or hazard rate key-functions and cosine, simple polynomial, or Hermite polynomial series expansion with stratification by vegetation type and using litter-depth, vegetation density, canopy cover, and canopy height as covariates. These covariates were assumed to be a priority to influence the detection probability. They were entered into the model as non-factors and examined their effect on the detection probability. The model with the least Akaike information criterion (AIC) was then selected and presented. Additionally, the Kolmogorov–Smirnov and the Cramér-von Mises goodness-of-fit tests were used. The Kolmogorov–Smirnov goodness-of-fit test focuses on the largest difference between the observed and expected distances where a p-value of < 0.05 is interpreted as a poor fit, while a p-value ≥ 0.05 interpreted as evidence for a good fit. On the other hand, the Cramér-von Mises goodness-of-fit tests use the overall departure (difference) between the observed and expected distances to indicate whether there are significant

TABLE 1 Estimates of $f(0)$, corresponding 95% confidence intervals (CI) and percentage coefficient of variation (% CV) for the three vegetation types

		95% CI		
Vegetation type	$f(0)$	Lower	Upper	% CV
Cynometra	0.212	0.169	0.268	11.55
Mixed forest	0.187	0.122	0.287	20.8
Brachystegia	0.137	0.043	0.431	58.99

problems. In this test, a *p*-value of <0.05 indicates significant problems in the departures between data and fitted models (Buckland et al., 2004; Burnham et al., 1980; Marques et al., 2007).

The resulting estimated nest densities for each vegetation type were then divided by a correction factor of 0.49 to take into account the multiple nest use by golden-rumped sengi and following a similar approach in previous studies (FitzGibbon & Rathbun, 1994; Ngaruiya, 2009).

This study employed the Huber's formula to calculate deadwood volume (Filho et al., 2000) where,

$$V = \frac{L\pi d_m^2}{4}$$

where V is the coarse woody debris volume, L is the length of the log and d_m is the mid-diameter of the log.

A linear regression model (Seber & Lee, 2012) was fitted to relate the number of old and new sengi nests and deadwood volume observed per transect for each vegetation type and overall for ASF.

Nest location characteristics were examined in each vegetation type. Means were computed for canopy cover, canopy height, litter depth and vegetation density (continuous variables) while percentages were calculated for nest material composition (categorical variable). Student's *t*-test was computed to assess the presence of significant differences in the means of the continuous variables by comparing the different vegetation types. Chi-square was then used to determine whether there was significant association between nest material composition and the vegetation types.

3 | RESULTS

3.1 | Detection probability

Nests were more likely to be detected in the *Cynometra* forest followed by Mixed-forest vegetation and least in the *Brachystegia* forest; however, the difference was not significant (95% CIs were overlapping). Table 1 shows the estimates of the detection function ($f(0)$). Figure 3 shows the plots for the detection probability of new and old sengi nests in *Cynometra*, mixed-forest and *Brachystegia* vegetation types, respectively.

A total of 112 (51 new and 61 old) nests were recorded in the 44 line transects placed across the three main vegetation types in ASF. Detection functions from the half-normal cosine models are presented since they had the least AIC (518.48) compared with those with hazard-rate key-function (530.65). This model provided a good fit as assessed by the Kolmogorov–Smirnov goodness-of-fit statistic across the three vegetation types where $D_n = 0.1479$ ($p = 0.1329$) in *Cynometra* forest, $D_n = 0.1085$ ($p = 0.9081$) and $D_n = 0.1388$ ($p = 0.7671$) in the mixed forest and *Brachystegia* vegetation types, respectively. This also provided evidence of no rounding of observed distances in the data. Again, the Cramer-von Mises goodness-of-fit test showed no significant departures between the observed data and the fitted model across all three vegetation types.

Estimates of the number of golden-rumped sengi per square kilometre (density) varied across the three vegetation types with the density being highest in the mixed-forest vegetation type (57 individuals [95% CI: 29–113]) whereas the *Brachystegia* vegetation type had the least density at 29 individuals [95% CI: 8–103] per square kilometre (Table 2). Overall, the estimated population of golden-rumped sengi across the three vegetation types of ASF was approximately 19,423 [11,612–35,198] individuals. Most individuals were found in *Cynometra* at about 13,160 [95% CI: 8939–19,939] while the least were estimated to exist in the *Brachystegia* vegetation type 2248 [95% CI: 640–7899].

Deadwood volume was on average higher in the *Brachystegia* vegetation type (about 0.13 m^3) than 0.12 m^3 and 0.09 m^3 in the mixed forest and *Cynometra*, respectively. The output from ordinary least square (OLS) regression models between deadwood volume (cubic meters) and the number of nest sightings in each transect (abundance) by vegetation type and overall are shown in Table 3. Although there was no evidence of significant association between deadwood volume and abundance—all coefficients had *p* values >0.05—abundance was positively associated with deadwood volume only in the *Cynometra* vegetation type where a cubic meter increase in deadwood volume was associated with a nearly double increase in abundance (1.96 [95% CI: −3.71 to 7.64; $p = 0.48$]).

There was variation in the canopy cover where sengi nests were found across the three vegetation types. Canopy cover was estimated to be, on average the highest in the mixed-forest vegetation (65% [95% CI 58.7%–71.3%]) compared with *Brachystegia* forest (55.7% [95% CI 49.1%–62.3%], $p = 0.0503$) and was lowest in the *Cynometra* forest (47.6% [95% CI 43.5%–51.8%], $p < 0.001$). Sengi nests were generally found in areas with litter depths of nearly

FIGURE 3 (a–c) Histogram of the estimated MCDS detection function for sengi nests in the three vegetation types. (a) Histogram of the estimated MCDS detection function for sengi nests averaged over the observed covariate values for litter depth, canopy cover, canopy height and vegetation density in the *Cynometra* vegetation type. (b) Histogram of the estimated MCDS detection function for sengi nests averaged over the observed covariate values for litter depth, canopy cover, canopy height and vegetation density in the Mixed-forest vegetation type. (c) Histogram of the estimated MCDS detection function for sengi nests averaged over the observed covariate values for litter depth, canopy cover, canopy height and vegetation density in the *Brachystegia* vegetation type.

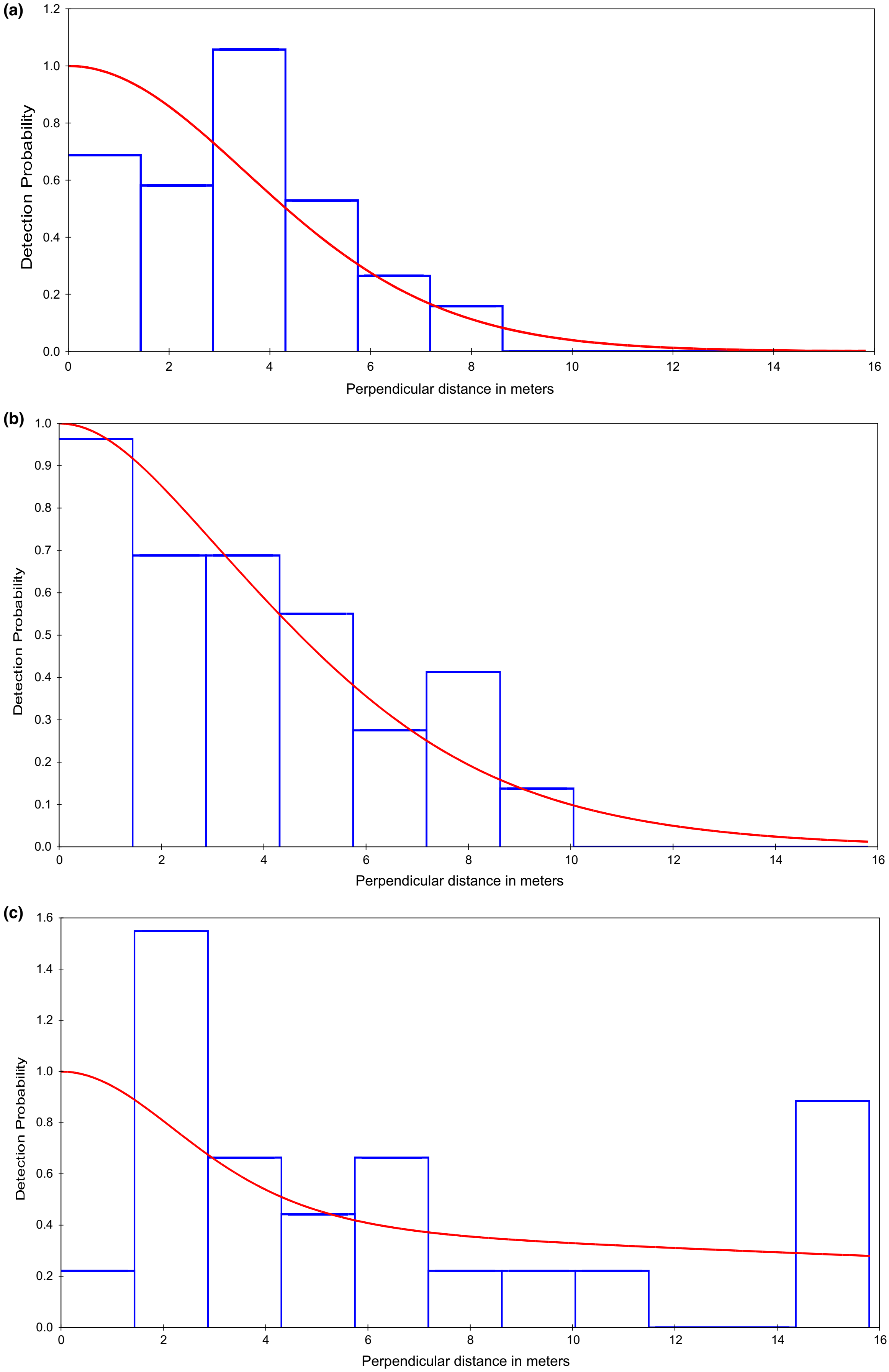
(a)
Detection Probability
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
14
16
Perpendicular distance in meters
(b)
Detection Probability
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
2
4
6
8
10
12
14
16
Perpendicular distance in meters
(c)
Detection Probability
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
2
4
6
8
10
12
14
16
Perpendicular distance in meters

TABLE 2 Density (*D*) (number per km^2) corresponding 95% confidence interval (CI) and abundance (*N*) and its corresponding 95% confidence interval (CI)

Vegetation type	Density (*D*)	95% CI for *D*	% CV for *D*	Habitat area (km^2)	Abundance (*N*)	95% CI for *N*
Cynometra	56.0	38.0–82.4	19.4	235	13,160	8939–19,372
Mixed forest	57.4	29.0–113.3	33.3	70	4015	2033–7927
Brachystegia	29.19	8.3–102.6	67.4	77	2248	640–7899
Total				382	19,423	11,612–35,198

TABLE 3 Ordinary least square (OLS) regression between deadwood volume (M^3) and the number of old and new sengi nest sightings by vegetation type and overall, across the three vegetation types

	Coefficient [95% CI]	*p*-Value	Observations	R^2
Cynometra	1.96 [−3.71 to 7.64]	0.480	24	0.023
Mixed forest	−3.10 [−18.51 to 12.32]	0.649	9	0.031
Brachystegia	−3.11 [−11.67 to 5.45]	0.432	11	0.070
Overall	−0.70 [−4.83 to 3.43]	0.734	44	0.003

TABLE 4 Distribution of golden-rumped sengi nests' (old and new) material composition by vegetation type in Arabuko-Sokoke Forest

Material composition	*Cynometra* *n* (%)	Mixed forest *n* (%)	*Brachystegia* *n* (%)	Overall *n* (%)
Twigs only	5 (8)	0 (0)	0 (0)	5 (4)
Leaves only	7 (11)	9 (33)	9 (38)	25 (22)
Leaves and twigs	50 (81)	18 (67)	15 (62)	83 (74)

TABLE 5 Comparisons of golden-rumped sengi abundance between 2019 and 2008

Vegetation type	Ngaruiya (2009)	[95% CI]	Present study (2019)	[95% CI]
Cynometra forest	9196	[7299–1109]	13,160	[8939–19,372]
Mixed forest	2080	[1774–2386]	4015	[2033–7927]
Brachystegia forest	1474	[1080–1868]	2248	[640–7899]
Total	12,750	[10,153–15,347]	19,423	[11,612–35,198]

1.41 cm (95% CI 1.26–1.55) on average. Although no significant difference was observed in litter depth among the three vegetation types, nests found in *Brachystegia* forest had marginally higher mean litter depth at 1.67 cm (95% CI 1.35–1.97) while that in the mixed forest was the least at 1.26 cm (95% CI 0.90–1.62).

Vegetation density was significantly higher for the old and new sengi nests found in the *Cynometra* forest (21.8% [95% CI 16.41–27.13]) compared with mixed forest (10.0% [95% CI 2.65–17.48], *p* = 0.015) and *Brachystegia* forest (9.8% [95% CI 5.07–14.62], =0.010). Sengi nests were found in areas with varying estimated canopy heights across the three vegetation types. Canopy height was, on average, the highest for the sengi nests found in the *Brachystegia* forest at 16.17 m [95% CI 13.82–18.52] followed by those in the mixed forest at 14.50 m [95% CI 12.23–16.77, *p*-value = 0.297] and the least for those in the *Cynometra* forest (9.76 m [95% CI 8.76–10.77], *p*-value < 0.001). Across all vegetation types, over 60% of old and new sengi nests were comprised of both leaves and twigs. However, some nests were found to be made of twigs only in the *Cynometra* forest unlike in the other vegetation types as outlined in Table 4. A Chi-square test of association between nest material composition and vegetation type showed strong evidence of association (*p*-value = 0.014).

4 | DISCUSSION

Our study examined the abundance and influence of deadwood volume on golden-rumped sengi nest sightings in ASF. We found that the total population of these sengi in ASF was 19,423 individuals using nest sites as a proxy. This population represents an increase compared to estimates from a previous study by Ngaruiya (2009) in which the total sengi population in the study area was 12,750 individuals (Ngaruiya, 2009). Similarly, *Cynometra* forest still had the highest number of individuals and mixed forest had the highest density (about 57.4). The sengi in *Cynometra*, mixed forest and *Brachystegia* had increased by about 43%, 93% and 53%, respectively (Table 5).

Although declines in golden-rumped sengi abundance of about 30% and 9% were reported between 1993–2000 and 2000–2008, respectively (Bauer, 2001; Ngaruiya, 2009), this study found their population had increased by nearly 52% since 2008. However, this previous study limited the width of the transect to 3 m unlike in our study. Consequently, these may have underestimated the abundance unlike in our study. In the two studies the old and new nests were used in estimating abundance.

The high number of sengi individuals across all vegetation types, especially in the *Cynometra* habitat can mainly be attributed to the habitat characteristics since the *Cynometra* habitat type is relatively dense with small diameter trees so their nests are not easily visible to predators such as birds of prey. On the other hand, *Brachystegia* forest is relatively open with trees that are tall and with large diameter making it relatively easier for predators to see sengi hence the low number although there was an increase compared to previous studies. Furthermore, the increase in the sengi numbers may reflect the conservation measures established, such as participatory forest management (Matiku et al., 2013), fencing of the forest in 2006/07 as well as livelihood improvement measures such as the Kipepeo project (Okeyo, 2013). However, as indicated in other studies abundance is not a good indicator of habitat quality since other factors can sustain the numbers, such as immigration (Weldy et al., 2019).

It was noted (FitzGibbon, 1994) that sengi did occur in some scrub and degraded woodland habitats, although at low densities. Anecdotal evidence has indicated they are found in disturbed areas such as Dakatcha woodlands. Additionally, their nests were also observed near the forest edge, which is generally associated with more logging and cut stumps (Bauer, 2001). Other studies (Yarnell et al., 2008) also observed that the short-snouted sengi could adjust to a new environment after their habitats were destroyed by fire. Specifically, they reported that the destruction of grasslands mainly used by elephant shrews as habitat resulted in a shift to the use of thickets than grass.

Likewise, a study conducted on small mammals in the Amazon showed increased abundance with habit features indicative of disturbed areas and this pattern was associated with increased resource abundances in these areas with insect biomass and number of fruiting trees showing similar relationships (Lambert et al., 2006). The variation in golden-rumped sengi population estimates could also be attributed to methodological differences from previous studies in which the detection distances on either side of the transects were limited to 3 m and more than one observer were involved in searching for the nests within the identified area (Bauer, 2001; FitzGibbon, 1994; Ngaruiya, 2009). This, therefore, does not meet the assumptions in distance sampling which this study met. In distance sampling, truncation of data is allowed for analysis purposes in which some distances beyond a certain point are discarded (Buckland et al., 1993). Also, it has been noted that precision was better for untruncated data for the hazard-rate model (Buckland et al., 1993). In addition, a study by Bauer, 2001 did not focus on the abundance but instead on the impact of commercial and subsistence practices using golden-rumped sengi as an indicator species.

There was no evidence of an association between deadwood volume and abundance. Deadwood was highest in *Brachystegia*, which had the lowest number of sengi individuals while it was the least in *Cynometra*, which recorded the highest numbers of sengi individuals. This suggests that as long as the sengi was within a forested habitat, availability of deadwood did not have an impact on nest location and consequently its presence, however, further research should be conducted to confirm this.

Additionally, this study indicated that a unit increase in vegetation density, litter depth, and canopy cover were associated with an increased chance of finding a nest. This could be attributed to several reasons. First, leaf litter is a main component of sengi nests thus golden-rumped sengi are more likely to construct nests where leaves are in abundance. Second, in another study, canopy cover, and leaf litter (litter depth) reduction were shown to reduce the golden-rumped sengi population as these provided cover against likely predators (Rathbun & Kyalo, 2000). Furthermore, leaves and twigs form a larger composition of litter in ASF and it was no surprise that these were the majority materials used for nest construction. According to Sponchiado et al. (2012), most species richness and abundance variability were associated with environments that offer more resources that is, food, water and shelter as was evidenced by the study on rodents. Small mammals are also sensitive to habitat structure (Novillo et al., 2017).

Findings from this study should also be interpreted with a consideration to the key methodological limitation that indirect approaches to estimating animal abundance have. Besides, while previous studies limited the distance for observing nests to three to either side of the transect, this study did not use this limitation, and therefore findings were not directly comparable.

5 | CONCLUSIONS

From the findings, the study concludes that, the population of golden-rumped sengi in ASF has increased, there was no significant association between deadwood and their nest sightings. Higher canopy cover, litter depth and vegetation density were associated with sengi nest sightings. The conservation measures that have been implemented are likely to have led to the increase since they discourage human activities within the forest, or it could indicate that the sengi are adapting to changes that are occurring within the forest. The study recommends further research to understand if there exist patterns of habitat selection and variation in and abundance of invertebrates that are consumed by these sengi.

ACKNOWLEDGEMENTS

We wish to thank The Mohammed Bin Zayed Species Conservation Fund, Nature Kenya, Pwani University, Kenya Wildlife Service (KWS) and Arabuko-Sokoke Forest (ASF) management. The work formed part of the requirements for the Masters of Science degree of Pwani University.

CONFLICT OF INTEREST

No conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available upon request from the author (raelnelly@gmail.com).

ORCID

Rael Nelly Nyanchama Ondoro https://orcid.org/0000-0001-8199-9407

REFERENCES

Arabuko-Sokoke Forest Management Team. (2002). *Arabuko-Sokoke strategic forest management plan 2002–2027*. Kenya Forest Services.

Baker, T., & Chao, K. (2011). *Manual for coarse woody debris measurement in RAINFOR plots*. Leeds.

Bauer, C. R. (2001). *Impact of commercial and subsistence practices on the Arabuko-Sokoke Forest in coastal Kenya, using an endemic mammal as an indicator species*. Eastern Kentucky University.

Bellard, C., Leclerc, C., Leroy, B., Bakkenes, M., Veloz, S., Thuiller, W., & Courchamp, F. (2014). Vulnerability of biodiversity hotspots to global change. *Global Ecology and Biogeography*, *23*(12), 1376–1386.

Buckland, S. T., Anderson, D. R., Burnham, K. P., & Laake, J. L. (1993). *Distance sampling: Estimating abundance of biological populations*. Chapman and Hall.

Buckland, S. T., Anderson, D. R., Burnham, K. P., & Laake, J. L. (2004). *Advanced distance sampling* (Vol. *2*). Oxford University Press.

Buckland, S. T., Rexstad, E. A., Marques, T. A., & Oedekoven, C. S. (2015). *Distance sampling: Methods and applications*. Springer.

Burnham, K. P., Anderson, D. R., & Laake, J. L. (1980). Estimation of density from line transect sampling of biological populations. *Wildlife Monographs*, *72*, 3–202.

Cook, R. P. (2001). Small Mammals, Big Role. Cape Cod National Seashore Newspaper, p. 1.

De Meo, I., Agnelli, A. E., Graziani, A., Kitikidou, K., Lagomarsino, A., Milios, E., Radoglou, K., & Paletto, A. (2017). Deadwood volume assessment in Calabrian pine (*Pinus brutia* Ten.) peri-urban forests: Comparison between two sampling methods. *Journal of Sustainable Forestry*, *36*(7), 666–686.

Eräjää, S., Halme, P., Kotiaho, J. S., Markkanen, A., & Toivanen, T. (2010). The volume and composition of dead wood on traditional and forest fuel harvested clear-cuts. *Silva Fennica*, *44*(2), 203–211.

Filho, A. F., Machado, S. A., & Carneiro, M. R. A. (2000). Testing accuracy of log volume calculation procedures against water displacement techniques (xylometer). *Canadian Journal of Forest Research*, *30*(6), 990–997.

FitzGibbon, C., & Rathbun, G. (2014). *Rhynchocyon chrysopygus*. The IUCN Red List of Threatened Species Version.

FitzGibbon, C. D., & Rathbun, G. B. (1994). Surveying *Rhynchocyon* elephant-shrews in tropical forest. *African Journal of Ecology*, *32*(1), 50–57.

FitzGibbon, C. D. (1994). The distribution and abundance of the golden-rumped elephant-shrew *Rhynchocyon chrysopygus* in Kenyan coastal forests. *Biological Conservation*, *67*(2), 153–160.

Habel, J. C., Casanova, I. C. C. C., Zamora, C., Teucher, M., Horntez, B., Shauri, H., Mulwa, R. K., & Lens, L. (2017). East African coastal forest under pressure. *Springer*, *26*(11), 2752–2758.

Lambert, T. D., Malcolm, J. R., & Zimmerman, B. L. (2006). Amazonian small mammal abundances in relation to habitat structure and resource abundance. *Journal of Mammalogy*, *87*(4), 766–776.

Lusweti, M. A. (2011). Biodiversity Conservation in Kenya. Institute of Economic Affairs, Issue 32.

Marques, T. A., Thomas, L., Fancy, S. G., & Buckland, S. T. (2007). Improving estimates of bird density using multiple-covariate distance sampling. *The Auk*, *124*(4), 1229–1243.

Matiku, P., Caleb, M., & Callistus, O. (2013). The impact of participatory forest management on local community livelihoods in the Arabuko-Sokoke Forest, Kenya. *Conservation and Society*, *11*(2), 112–129.

Ndalilo, L., Mbuvi, M., & Luvanda, A. (2017). *Utilization and governance of Arabuko Sokoke Forest*. Biodiversity Status of Arabuko Sokoke Forest (pp. 47–59). Kenya Forest Research Institute.

Ngaruiya, G. (2009). *Assessment of the range and population of Golden-rumped elephant-shrew (Rhynchocyon chrysopygus) in the northern coastal forests of Kenya*. Biological Sciences, University of Nairobi Unpublished MA Thesis.

Novillo, A., Cuevas, M. F., Ojeda, A. A., Ovejero, R. J., Torres, M., Eugenia, M., & Ojeda, R. A. (2017). Habitat selection and coexistence in small mammals of the southern Andean foothills (Argentina). *Mammal Research*, *62*(3), 219–227.

Okeyo, R. O. (2013). *Impacts of Kipepeo conservation project on livelihoods and climate change mitigations among Arabuko Sokoke communities, Kilifi County, Kenya*. Kenyatta University.

Rathbun, G. (2009). Why is there discordant diversity in sengi (Mammalia: Afrotheria: Macroscelidea) taxonomy and ecology? *African Journal of Ecology*, *47*(1), 1–13.

Rathbun, G., & Kyalo, S. (2000). *Golden-rumped elephant-shrew*. Greenwood Press.

Rovero, F., Collett, L., Ricci, S., Martin, E., & Spitale, D. (2013). Distribution, occupancy, and habitat associations of the gray-faced sengi (*Rhynchocyon udzungwensis*) as revealed by camera traps. *Journal of Mammalogy*, *94*(4), 792–800.

Rovero, F., Rathbun, G. B., Perkin, A., Jones, T., Ribble, D. O., Leonard, C., Mwakisoma, R. R., & Doggart, N. (2008). A new species of giant sengi or elephant-shrew (genus *Rhynchocyon*) highlights the exceptional biodiversity of the Udzungwa Mountains of Tanzania. *Journal of Zoology*, *274*(2), 126–133.

Seber, G. A., & Lee, A. J. (2012). *Linear regression analysis* (Vol. *329*). John Wiley & Sons.

Smit, H. A. (2008). *Phylogeography of three southern African endemic elephant-shrews and a supermatrix approach to the Macroscelidea*. Stellenbosch University.

Sponchiado, J., Melo, G., & Cáceres, N. (2012). Habitat selection by small mammals in Brazilian Pampas biome. *Journal of Natural History*, *46*(21–22), 1321–1335.

Thomas, L., Buckland, S. T., Rexstad, E. A., Laake, J. L., Strindberg, S., Hedley, S. L., Bishop, J. R., Marques, T. A., & Burnham, K. P. (2010). Distance software: Design and analysis of distance sampling surveys for estimating population size. *Journal of Applied Ecology*, *47*(1), 5–14.

Wekesa, C. (2017). *Biodiversity status of Arabuko Sokoke Forest, Kenya*. Kenya Forestry Research Institute.

Weldy, M. J., Epps, C. W., Lesmeister, D. B., Manning, T., Linnell, M. A., & Forsman, E. D. (2019). Abundance and ecological associations of small mammals. *The Journal of Wildlife Management*, *83*(4), 902–915.

Yarnell, R. W., Metcalfe, D. J., Dunstone, N., Burnside, N., & Scott, D. M. (2008). The impact of fire on habitat use by the short-snouted elephant shrew (*Elephantulus brachyrhynchus*) in north West Province, South Africa. *African Zoology*, *43*(1), 45–52.

How to cite this article: Ondoro, R. N. N., Okeyo, B., & Jackson, C. (2023). Examining the abundance and habitat use of golden-rumped sengi (*Rhynchocyon chrysopygus*) in Arabuko-Sokoke Forest in Kenya. *African Journal of Ecology*, *61*, 336–344. https://doi.org/10.1111/aje.13111