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Terrestrial mollusc species richness and diversity in Omo Forest Reserve, Ogun State, Nigeria

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ABSTRACT

The terrestrial mollusc species richness and diversity in Omo Forest Reserve, Ogun State, Nigeria, was studied using a combination of direct search and leaf-litter sieving techniques. In total, 28 species and 639 individuals in 7 molluscan families were collected from 17 plots of 400 m^2 each. Species richness varied from 3 to 14 (mean 8.59) and the number of individuals from 8 to 67 (mean 37.59) per plot. Species richness was dominated by the carnivorous Streptaxidae (36%) and herbivorous Subulinidae (32%), and numerical abundance by the Subulinidae (56%) and Streptaxidae (32%). The most abundant species was the large subulinid, *Subulona pattalus*, contributing almost 25% of the total number of individuals. Terrestrial molluscs with small populations and narrow distributional ranges are at great risk of local extinction if forest destruction continues unabated. Studies on the molluscan diversity in Omo Forest Reserve will assist in producing an inventory for biodiversity conservation management in Nigeria.

KEY WORDS: Mollusca, West Africa, Nigeria, slugs, snails, biodiversity, protected areas.

INTRODUCTION

Knowledge of the biodiversity in different ecosystems in tropical rainforest is urgently needed, given the high rate of deforestation and species loss as a result of anthropogenic activities. In most African forests, the fauna (especially invertebrates) is poorly studied and many species are yet to be described (Lydeard *et al*. 2004). Hence, the destruction of a small patch of rainforest will invariably lead to the extinction of many unidentified species. Omo Forest Reserve is one of such reserves seriously threatened by conversion to plantations of arable and cash crops (Persson & Warner 2003; Ojo 2004), with serious consequences for the biodiversity.

Omo Forest Reserve is one of six large contiguous forest reserves in Ogun State, south-western Nigeria, established to protect the biodiversity of the region (Persson & Warner 2003). The reserve is one of the few remaining habitats with old-growth tropical rainforest in Ogun State and is severely threatened by logging, poaching and plantation agriculture. Plantations of the exotic gmelina trees (*Gmelina arborea*) were begun over 40 years ago, with a view to supplying pulpwood to the nearby paper mill (Lowe 1993). Previous studies on biodiversity of the reserve focused on large vertebrates (Johansen 1994; Persson & Warner 2003), and little is known about the numerous invertebrates that constitute the majority of the fauna.

Presently, the reserve is in a poor state, lacking government funding, basic infrastructure, and facilities to protect the fauna and flora. Although Omo Forest Reserve has a moderately rich biodiversity, we do not know how long the forest will remain intact, because of the high demand for arable land and wood (Ojo 2004).

Molluscs are good indicators of environmental history and conditions because of their low mobility, long evolutionary history and calcareous shells that have a good preservation potential. The highest number of recorded extinctions in modern times have been amongst molluscs (Strayer *et al*. 1986; Lydeard *et al*. 2004; Régnier *et al.*

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2009) and many more species are threatened. Molluscs are easy to sample and their calcareous shells remain relatively intact for some time before disintegrating. Land snail shells serve as a calcium source for various organisms that feed on them, especially for eggshell formation, muscle contraction, and osmoregulation (Graveland & van der Wal 1996; Hottop 2002). In the forest ecosystem, land snails are preyed upon by a number of organisms including insects (beetles), amphibians, reptiles, birds and mammals. Hence, loss of land snail species as a result of deforestation has more far-reaching consequences on other organisms than can be imagined.

In continuation of my biodiversity studies on the land mollusc faunas in Nigeria, I collected samples from the old-growth rainforest reserve in Omo, Ogun State, south-western Nigeria. Previous studies on land molluscs in the region include the description of a new species, *Ptychotrema shagamuense* (Oke & Odiete 1996), and research carried out in Erin Ijesha (Oke 2007), Okomu Forest Reserve (Oke & Alohan 2006), Ekpoma (Oke *et al*. 2007*b*), Egbeta (Oke *et al*. 2008), and Idanre hills (Oke & Chokor 2010). In this paper, I report on the species richness and diversity of land molluscs collected from Omo Forest Reserve, Ogun State, Nigeria.

MATERIAL AND METHODS

Study area

Omo Forest Reserve is located in Ijebu Province of Ogun State, south-western Nigeria (6°35'–7°05'N 4°19'–4°40'E; Fig. 1). The reserve was established in 1925 and covers about 130,500 ha. The terrain is undulating with occasional rocky outcrops and inselbergs and with a maximum elevation of 300 m above sea level. Geologically, the reserve lies on crystalline rocks of undifferentiated basement complex, which in the southern parts

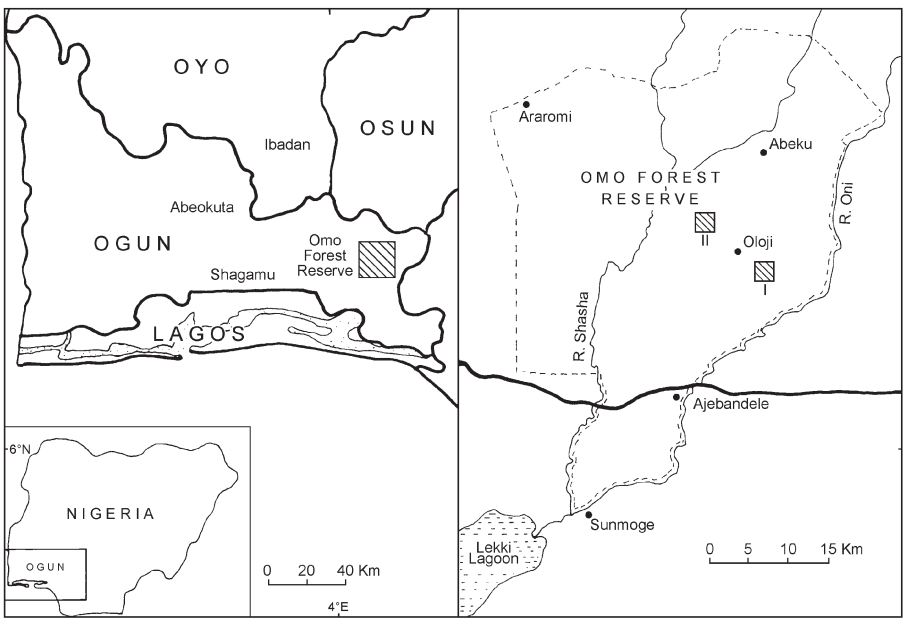

Fig. 1. The location of Omo Forest Reserve in Ogun State, Nigeria. Site I includes plots (1–12) sampled in 2009 and site II plots (13–17) sampled in 2010.

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is overlain by Eocene deposits of sand, clay and gravel (Onyekwelu 2005). The reserve is drained by River Omo that flows south, where it joins River Oni before flowing into the Lekki Lagoon, then into the Atlantic Ocean. The climate is tropical, with two distinct seasons: rainy (March–October) and dry (February–October). Mean annual rainfall ranges from 1600–2000 mm (Allison 1955; Ojo 2004). The vegetation is characterised by a mixture of dry and moist evergreen rainforest (Lowe 1993).

Sample collection

Land mollusc samples were collected during the rainy season in June 2009 and 2010 using a combination of direct search and litter-sieving techniques (e.g. Tattersfield 1996). Direct searching involved examination in a plot of 20×20 m of all potential molluscan microhabitats that could be accessed, such as fallen tree trunks, deep litter beds, rock faces, *etc*.

Seventeen plots were sampled, 12 in 2009 (site I; Fig. 1) and five in 2010 (site II). The plots (1–12) in site I were located in a portion of the reserve that is regenerating after selective logging activities about 40 years ago, while those in site II (13–17) were situated near a cocoa plantation within the reserve. Each plot was approximately 50 m apart from the next one, placed alternately from the previous one. At each plot, we searched intensively for molluscs for two person-hours (i.e. two searchers active for one hour). In addition, we collected an average of 50 litres of litter and topsoil from 10 randomly selected 1×1 m sites within each plot. Litter samples and top soil were exhaustively searched in the laboratory for land molluscs. All live slugs and snails, and all empty shells were collected. Live specimens were drowned and preserved in 70% ethanol.

Data analysis

The diversity was measured as overall species richness (S) and Whittaker's index (I), which is the total number of species recorded (S) divided by the mean number of species per site (α), providing a measure of diversity difference between sites (Schilthuizen & Rutjes 2001). The true diversity was estimated by performing 100 randomisations on the data and calculating S using the Chao 2 and second-order jackknife richness estimators in the program EstimateS 7.5 (Colwell 2006). We used sample-based rarefaction curves to produce a smooth curve that estimates the number of species that would be observed for any smaller number of samples, assuming random mixing of sample order (Colwell & Coddington 1994; Gotelli & Colwell 2001). We defined sample intensity as the ratio of individuals to species and inventory completeness as the percentage of observed number of species over the expected number of species as estimated by Chao2 or Jack2 (Coddington *et al.* 1996; Soberon *et al*. 2007). Statistical analyses were performed using the PAST software (Hammer *et al*. 2001). Hierarchical clustering (Bray-Curtis similarity measure) was used to identify natural groupings among the sampled points according to similarities in their species composition. Cluster analysis is the arrangement of samples into groups (cluster), so that samples within the same cluster are more similar to each other than to samples from different clusters (Gauch & Whittaker, 1981). The non-parametric one-way Analysis of Similarity (ANOSIM; Clarke 1993) was used to test for statistical differences in species composition between clusters. Similarity Percentage (SIMPER; Clarke 1993) analysis, using the Bray-Curtis similarity measure, was used to assess which taxa are responsible for an observed difference between groups of samples.

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RESULTS

In total, 639 individuals belonging to 28 species in 18 genera and 7 families of pulmonate molluscs were collected (Figs 3–26). Each plot yielded between 8 and 67 individuals (mean 37.57, standard deviation 19.33) and between 3 and 14 species (mean 8.59, standard deviation 3.36). The species collected from all the sample plots are listed in Table 1. Two families are most species-rich and abundant: Streptaxidae, represented by 10 (36 %) species and 202 (32 %) individuals, and Subulinidae with 9 (32 %) species and 361 (56 %) individuals.

A few species were very abundant, few very rare, while most were intermediate in abundance (Fig. 2). Five species occurred with more than 50 individuals, 15 species occurred with fewer than 10 individuals, two as doubletons, and two as singletons. The most abundant species contributed about 69 % of the total number of individuals: *Subulona pattalus* (Pilsbry) (25.20 %), *Ptychotrema shagamuense* Oke & Odiete (12.21 %), *Striosubulina striatella* (Rang) (12.05 %), *Subulona involuta* (Gould) (10.02 %), and *Gonaxis camerunensis* (d'Ailly) (9.39 %).

The rarefaction curves (Fig. 27) almost reached an asymptote when sampling stopped and the number of species recorded was not different from that obtained by the non-parametric estimators. Estimated species richness based on Chao 2 and Jack 2 gave values of 28.35 and 27.68 species respectively. 'Sample intensity' (ratio of individuals to species) was 22.82:1, while inventory completeness was 98.77 % using Chao2 estimator. Whittaker's index was 3.26, indicating high differentiation among plots.

Although inventory completeness was 90 % and 98 % for site I and site II, respectively, using Chao2 estimator, comparatively more species were collected from site I (25 species) than site II (18 species), and there was a significant difference in species composition between the two sites. Moreover, the dendrogram of similarity divided

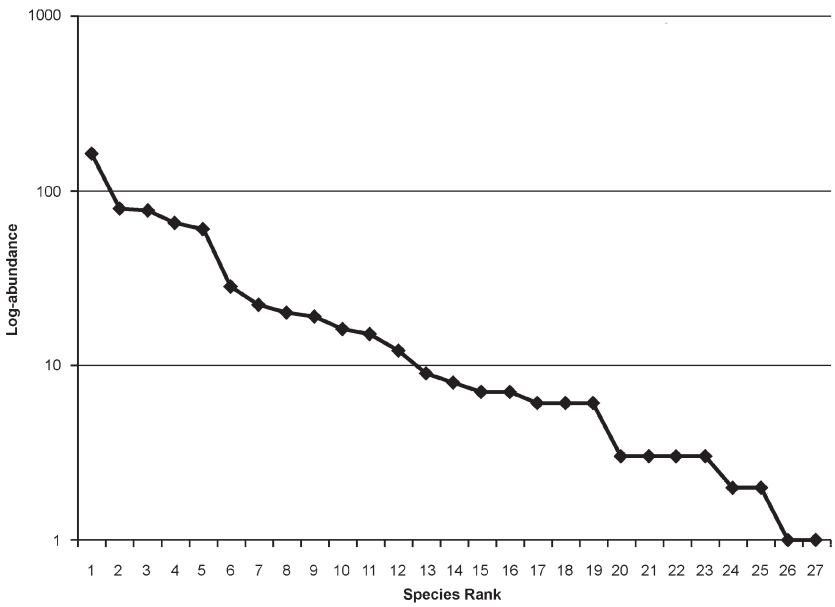

Fig. 2. Rank abundance curve for terrestrial snails from Omo Forest Reserve in Ogun State, Nigeria.

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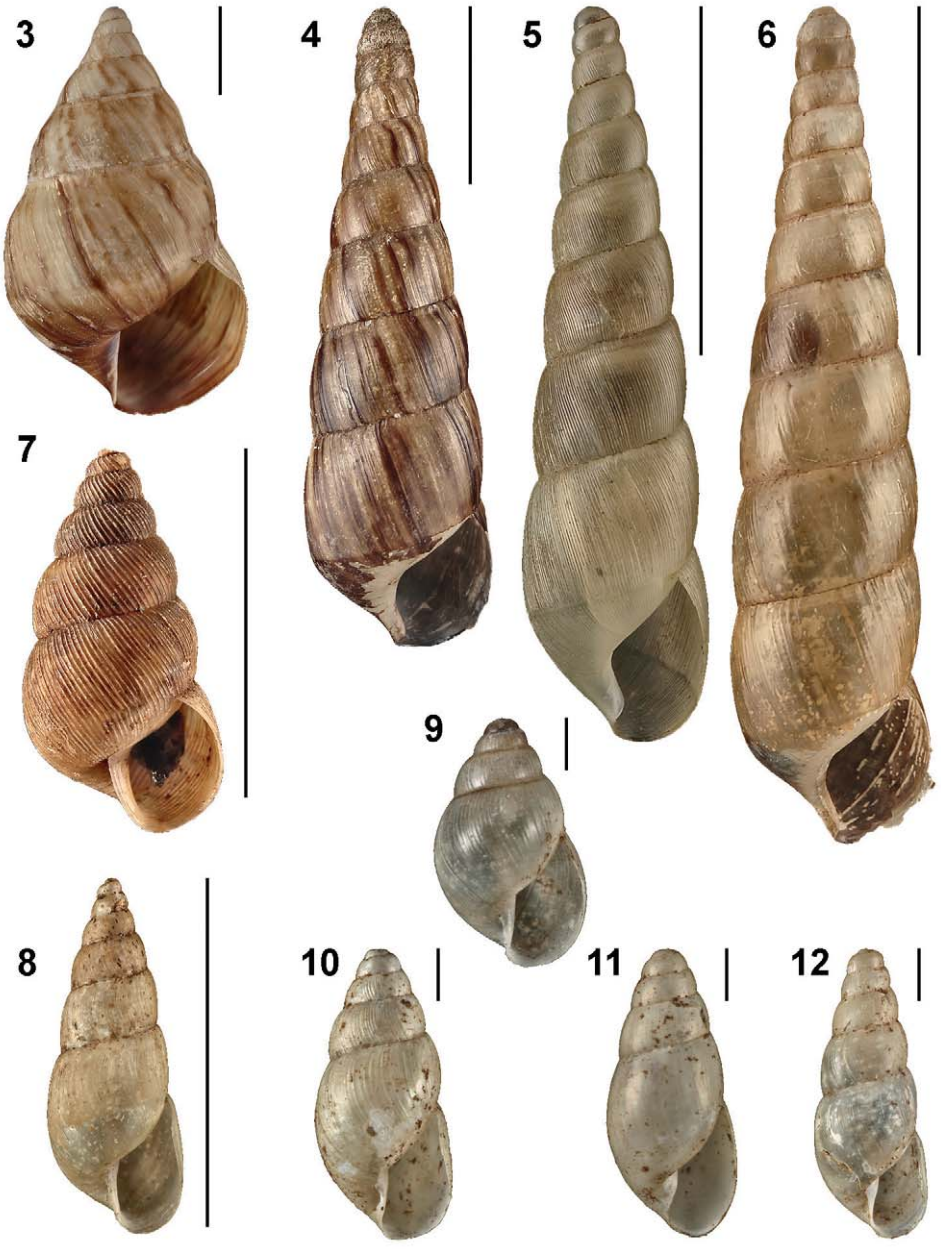

Figs 3–12. (3) Achatinidae, *Lignus* sp., H 46 mm; (4–12) Subulinidae: (4) *Subulona pattalus*, H 36 mm; (5) *Striosubulina striatella*, H 21.1 mm; (6) *Subulona involuta*, H 24 mm; (7) *Kempiochoncha stuhlmanni*, H 11 mm; (8) *Pseudopeas curvelliforme*, H 10.2 mm; (9) *Curvella feai*, H 4.8 mm; (10) *Curvella ovata*, H 5.6 mm; (11) *Curvella* sp. juvenile, H 5.52 mm; (12) *Pseudopeas* cf. *ukaguruense*, H 5.52 mm. Scale bars = 10 mm (Figs 3–8) and 1 mm (Figs 9–12).

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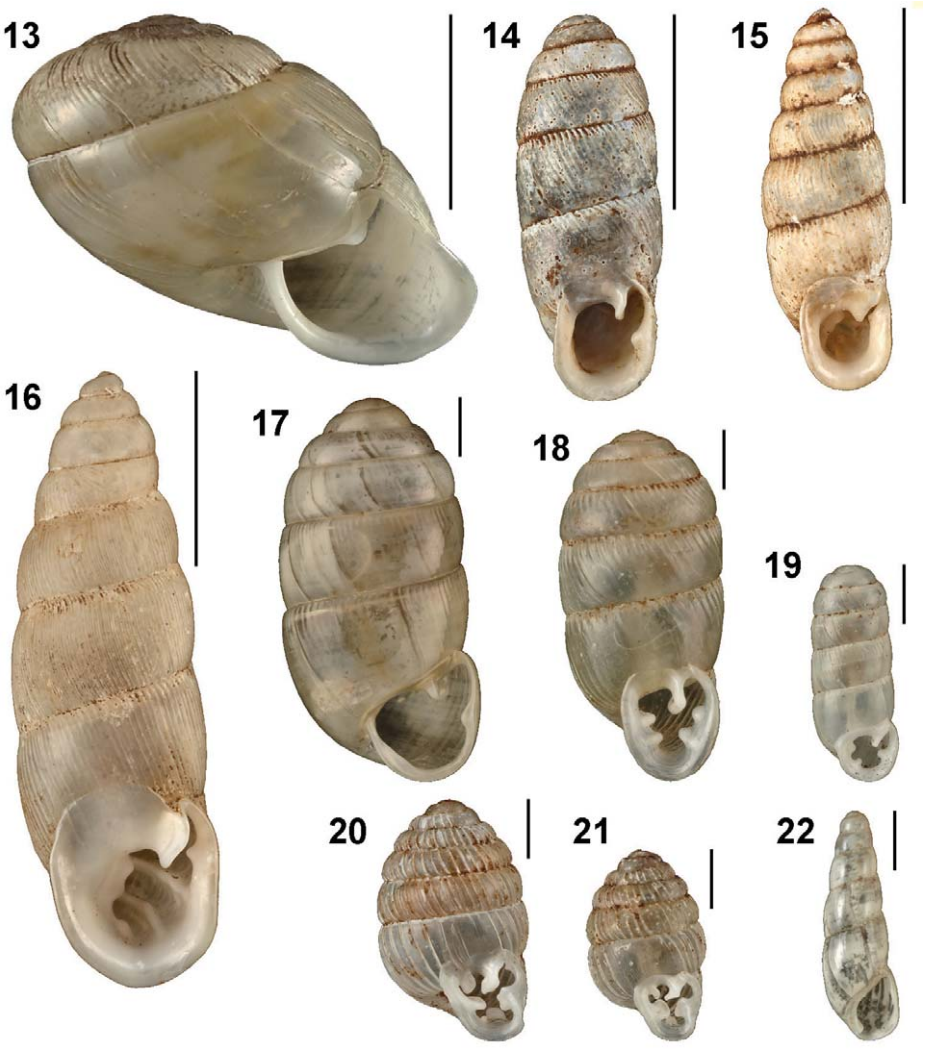
the plots into two distinct groups at 50 % similarity (Fig. 28). Plots (1–4, 6–8) in site I formed one cluster, and plots (13–17) in site II formed the second group. Analysis of Similarity, using the Bray-Curtis similarity index, revealed significant differences in species composition between the two clusters (R=0.99, p=0.0009), indicating that the sites were well separated. SIMPER analysis revealed that the taxa primarily responsible for the observed difference between the two groups include *S. pattalus* (24.72 %), *G. camerunensis* (16.62 %), *P. shagamuense* (12.05 %), *S. involuta* (10.37 %), and *S. striatella* (9.85 %).



Figs 13–22. Streptaxidae: (13) *Gonaxis camerunensis*, H 9 mm; (14) *Ptychotrema okei*, H 9.9 mm; (15) *Ptychotrema* sp., H 9.8 mm; (16) *Ptychotrema shagamuense*, H 15.8 mm; (17) *Gulella monodon*, H 6.48 mm; (18) *Gulella reesi*, H 5.92 mm; (19) *Gulella io*, H 3.64 mm; (20) *Gulella jongkindi*, H 4.08 mm; (21) *Gulella* cf. *opoboensis*, H 3.24 mm; (22) *Tomostele musaecola*, H 3.84 mm. Scale bars = 5 mm (Figs 13–16) and 1 mm (Figs 17–22).

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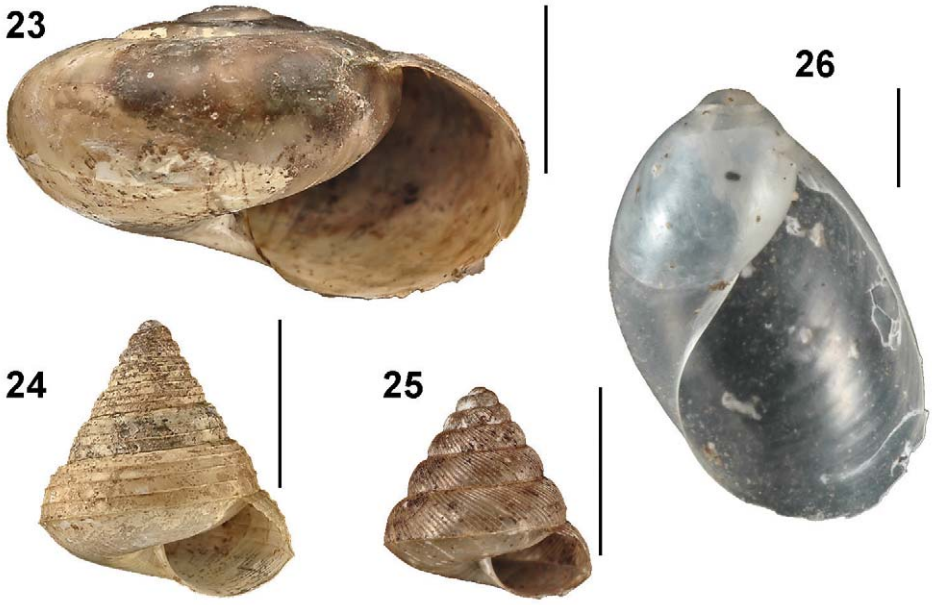

Figs 23–26. (23–25) Urocyclidae: (23) *Thapsia oscitans*, H 8.8 mm; (24) *Trochozonites talcosus*, H 8.3 mm; (25) *Trochozonites adansoniae*, H 6.3 mm; (26) Aillyidae, *Aillya camerunensis*, H 4.4 mm. Scale bars = 5 mm (Figs 23–25) and 1 mm (Fig 26).

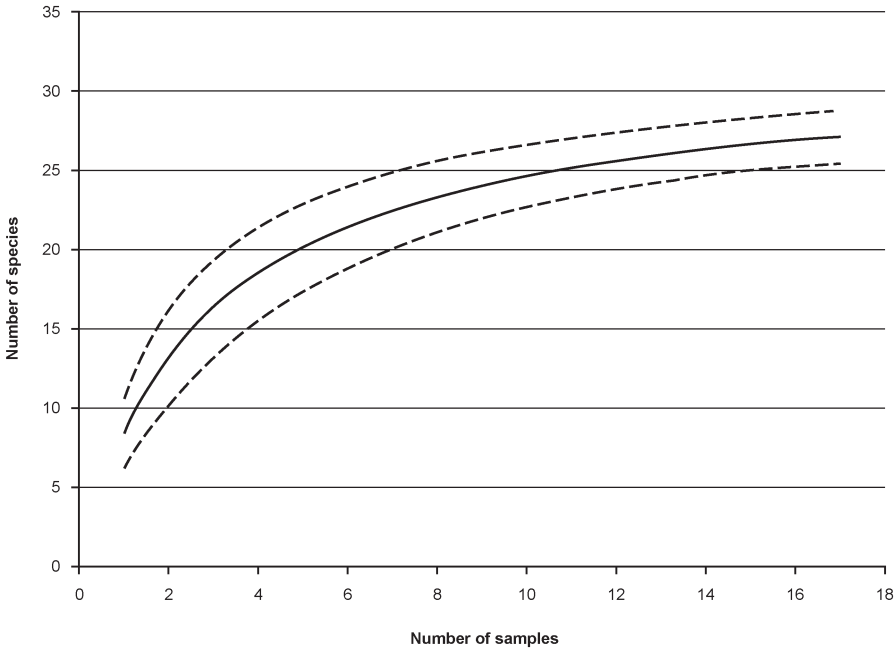

Fig. 27. Sample-based species accumulation curves for terrestrial molluscs in Omo Forest Reserve, Ogun State, Nigeria. Plotted values are means based on 100 randomisations of sample accumulation order (without replacement). Solid line, species observed; dashed lines, 95 % confidence limit.

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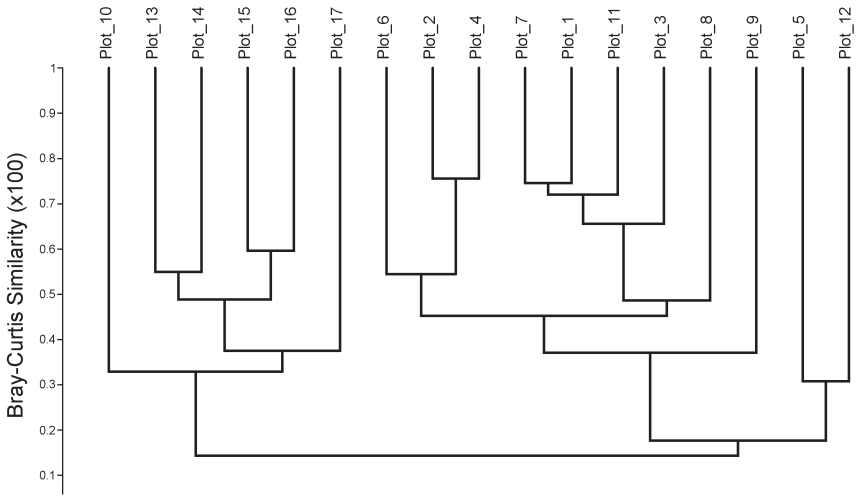

Fig. 28. Dendrogram of Bray-Curtis similarity between plots in sites I and II.

DISCUSSION

The sampling protocol was adequate in capturing most of the species recorded in sites within the study area in that the number of species recorded was similar to that obtained using the Chao 2 and Jackknife 2 non-parametric richness estimators (Colwell & Coddington 1994). However, when the two sites sampled were compared using ANOSIM, the faunal composition between the two sites was clearly different (R=0.99, p=0.0009). This means that other parts of the forest may be inhabited by an entirely different set of species and more species could still be found, despite the high inventory completeness recorded. Therefore, in order to get a complete inventory of the entire reserve, more samples may have to be collected. This is also borne out by the fact that some species commonly found in south-western Nigeria were missed by our sampling methods or may be locally extinct in the area sampled. For example, *Archachatina papyracea*, *Rachistia* sp. and *Quickia* sp. were not encountered during the collection in Omo Forest Reserve before (Oke & Chokor 2010) or during the present study.

Comparatively, the number of species recorded in Omo was higher than those recorded from agricultural plantations and some secondary forests within the region (Oke & Ugiagbe 2007; Oke *et al*. 2008), but lower than those obtained from lowland rainforest reserves and hills in Nigeria and other parts of western Africa (de Winter & Gittenberger 1998; Oke & Alohan 2006; Oke *et al*. 2007*a*; Fontaine *et al*. 2007; Oke 2007). Nevertheless, Omo Forest Reserve is moderately rich in mollusc species, especially the streptaxids and subulinids, given the high heterogeneity between plots (Whittaker's Index, 3.26) and between sites. Each site within the reserve has its own unique set of fauna and species richness. Considering the high heterogeneity between plots and between sites, destruction of a small patch of the remaining rainforest within the reserve may lead to the loss of some species.

Interestingly, the abundance of *Subulona pattalus* is unique for the region. This species is the largest subulinid snail recorded in Nigeria (shell length >40 mm) and has been uncommonly found previously in low numbers within the rainforest zone extending

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from Shagamu to Benin City (Oke & Alohan 2006; Oke 2007; Oke *et al*. 2007*b*, 2008; Oke & Chokor 2010; Chokor & Oke 2011). In a similar study carried out in Gabon, Fontaine *et al*. (2007) also found a subulinid to be the most abundant species. Hence, it will be of great value to monitor the population of this species in order to evaluate its conservation status.

The threats to biological diversity fall into several categories, including habitat loss and degradation, over-exploitation of natural resources, climate change, pollution, the spread of invasive species, and lack of effective policies (Pullin 2002). The land mollusc fauna of Omo Forest Reserve face a number of threats, including clearing the few remaining lowland forests for agricultural purposes or for timber. Timber harvesting not only degrades the habitats directly but also involves the construction of pathways and roads which further degrades other components of the ecosystem. Land molluscs with small populations and narrow ranges are at great risk of local extinction if the forest is destroyed. For example, the giant African land snail, *Archchatina marginata*, a delicacy and source of protein for the humans in the region, used to be very abundant in the past but is now becoming rare in many parts of southern Nigeria as a result of habitat destruction and degradation (Segun 1975; Ajayi *et al*. 1978; Oke & Odiete 2007).

In conclusion, the collecting effort put in has ensured that the survey was effective in obtaining a first inventory of terrestrial molluscs in Omo Forest Reserve. Furthermore, it has provided basic data on heterogeneity and the abundance or rarity of species, and has revealed the presence of potentially undescribed molluscs. This knowledge will help reserve managers to monitor the populations of various mollusc species that may be threatened in the future and also assist conservation planners to know the importance of incorporating invertebrates in reserve selection and management. Further studies on invertebrates will enable determination of the extent to which species and secondary production are lost as a result of forest destruction or degradation.

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TABLE 1

List of terrestrial molluscs recorded in Omo Forest Reserve, with number of specimens collected. Families, genera and species appear alphabetically.

	Families/genera/species	Plots																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
	Achatinidae																		
1	*Archachatina marginata* (Swainson, 1821)	3										2			1			2	8
2	*Lignus* sp.											1	1						2
3	*Limicolaria flammea* (Müller, 1774)	1										1							2
	Aillyidae																		
4	*Aillya camerunensis* (Odhner, 1927)							1			2	3							6
	Euconulidae																		
5	*Afropunctum seminium* (Morelet, 1873)													2			1		3
	Streptaxidae																		
6	*Gonaxis camerunensis* (d'Ailly, 1896)												1	14	17	13	8	7	60
7	*Gulella io* (Verdcourt, 1974)											1		4	1				6
8	*Gulella jongkindi* (de Winter, 1996)					2	1		1		6			1	7	3	1		22
9	*Gulella monodon* (Morelet, 1873)	3						2	1	2		3		2	1		2		16
10	*Gulella reesi* (Preston, 1914)										1								1
11	*Gulella* cf. *opoboensis* (Preston, 1914)														2	1			3
12	*Ptychotrema okei* (de Winter, 1996)		2		1	1	1	2											7
13	*P. shagamuense* (Oke & Odiete, 1996)	18	6	11	6	1	8	9	8	1	2	5	1	1	1				78
14	*Ptychotrema* sp.	1						1	2	1		1							6
15	*Tomostele musaecola* (Morelet, 1860)										2					1			3

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TABLE 1 (*continued*)

List of terrestrial molluscs recorded in Omo Forest Reserve, with number of specimens collected. Families, genera and species appear alphabetically.

	Family/genus/species	Plots																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	Total
	Subulinidae																		
16	*Curvella feai* Germain, 1915						2	1						5	4		2	6	20
17	*Curvella ovata* (Putzeys, 1899)							1								1			2
18	*Curvella* sp. juv.												1						1
19	*Kempiochoncha stuhlmanni* (von Martens, 1895)					8							1						9
20	*Pseudopeas curvelliforme* Pilsbry, 1919							1		1				1					3
21	*Pseudopeas* cf. *ukaguruense* Verdcourt, 1996						2	3		2	1			2	1		1		12
22	*Striosubulina striatella* (Rang, 1831)	6		5			1	8	20		9	3		1	16	5	3	12	89
23	*Subulona involuta* (Gould, 1843)				3		1				9	5		25	8	3	3	7	64
24	*Subulona pattalus* (Pilsbry, 1905)	23	10	41	16	3	4	22	9	7	2	23	1						161
	Urocyclidae																		
25	*Thapsia oscitans* (Connolly, 1925)	3		3	1	2		5	1	1		3		5	1			3	28
26	*Trochozonites adansoniae* (Morelet, 1848)									1									1
27	*Trochozonites talcosus* (Gould, 1850)	3				1		1			1	1	2	2	3	5			19
	Veronicellidae																		
28	*Pseudoveronicella liberiana* (Gould, 1950)													2	1	2	2		7
	Total no. of individuals	61	18	60	27	18	20	57	42	16	35	52	8	67	64	34	23	37	639
	Total no. of species	9	3	4	5	7	8	13	7	8	10	13	7	14	14	9	9	6	28

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