Composition and distribution of terrestrial molluscs in relation to soil calcium and pH levels in parts of northern Nigeria

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Abstract

The composition and distribution of terrestrial molluscs was studied for three years in different terrestrial habitats in northern Nigeria. This was done to determine the terrestrial mollusk fauna, establish their taxonomic positions and assess the relationships of soil calcium and pH to their distribution. Area sampling technique was employed using a small-scaled grid map of northern Nigeria. Possible collection sites were determined on the basis of on-the-spot-assessment of the potential sample areas. Molluscs were collected over a period of three years, during the wet and dry seasons. The molluscs collected were identified using standard taxonomic guides. Soil samples were analyzed for calcium and pH. A total of twelve (12) species of terrestrial molluscs belonging to six (6) families were recorded. The family Achatinidae occurred throughout the area of study. Only one family of slugs (Veronicellidae) was recorded. Five (5) of the six (6) families were represented by a single species each. The soil calcium content of the sites of molluscs collection averaged at 1.98 ± 0.31 Cmol/kg and the median value (50th percentile) for soil pH is at 6.57. These soil factors were positively correlated ($p<0.01$; $r = 0.93$). Terrestrial snails showed preference for soil calcium level of 1.75 to 2.00 Cmol/kg and pH levels between 6.25 and 6.50 and 7.0 to 7.25. The terrestrial ecosystems in northern Nigeria support a highly diversified malacofauna of ecological and probably of public health significance. Aside the level of precipitation and moisture retention of areas of occurrence, soil calcium and pH appeared to be important factors in the distribution of terrestrial molluscs.

Keywords: Terrestrial mollusks; soil calcium; pH; northern Nigeria.

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Introduction

The class Gastropoda, constitutes the largest and most diverse group of the phylum Molluscan that has undergone extensive adaptive radiation and, ecologically, has spread its species to a wider range of habitats than any molluscan group (Marshall and Williams, 2003). The gastropods are widely represented in freshwater habitats. By developing an effective water economy and investing in a modified excretory physiology, one large sub-class, the Pulmonata, has become typically terrestrial (Marshall and Williams, 2003).

The tropics have the greatest diversity of mollusc species both on land and in water (Janus, 1965; Fretter and Peake, 1978). Most of the estimated 30,000 to 35,000 land-snail species of the world are in the tropics (Solem, 1984). Majority remain undiscovered and undescribed, partly because of under-exploration, and partly because of their often minute sizes (Cowie, 1995). Land molluscs (pulmonates) occur in most parts of the globe, extending from hot deserts to beyond the Arctic Circle (Barker, 2002). With an estimated 35,000 species, terrestrial molluscs are one of the most successful and diverse animal groups in land-based ecosystems (Willem, 1975).

Land molluscs are damp atmosphere animals, found in habitats such as banks of water courses and ponds, marshes, damp meadows, especially such that have dead leaves, tree stumps, rotten wood and thickets of vegetation. The single most important factor determining land snail species number is area. Welter-Schultes and Williams (1999) reported that habitat diversity affected species' richness even after accounting for the effects of area; both increased elevation and greater extent of calcareous substrate on islands resulted in higher species number.

A number of factors that include soil pH, soil calcium content, precipitation and canopy density are reported to affect the distribution and activity of land snails (Sen *et al* 2012). Calcium availability in the soil is a major limiting factor for their survival as it is required for their

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shell formation. Studies have shown that soil calcium concentration is positively and significantly ($p \leq 0.05$) correlated with land snail species richness and abundance (Hotopp 2002; Aravind 2005; Chokor and Oke, 2011). McLaughlin and Wimmer (1999) reported on the importance of calcium availability in forest ecosystem processes and therefore calciphilic species of snails and plants were found to be associated with the highest calcium sites (Beier *et al* 2012). Soils with pH values between 4 and 5 are known to support high slug species richness (Idohou *et al* 2013) while the abundance of *Limicolaria flammea* and *Archachatina marginata* was negatively associated with the fine silts and soil pH.

Snails, semi-slugs and slugs are closely related and majorly constitute the bulk of terrestrial molluscs. Of the six orders of pulmonates, the Onchidiacea and Soleolifera are solely slugs. A third family, the Sigmurethra, contains various clades of snails, semi-slugs and slugs (Burton, 1982). The family Achatinidae is a diverse group of large pulmonate land snails that originated from western, eastern and southern Africa (Mead, 1961). Today, giant African land snails are found far outside their original area of distribution. However, snails require an environment containing large quantities of calcium-rich materials, including lime ($CaCO_3$). Materials containing calcium are necessary for the snail to develop its shell. Therefore, most snails are found in areas with calcium-rich soil (Nielsen, 1988).

Despite the important roles and contributions of molluscs to natural processes, there is still paucity of information on the molluscan fauna in northern Nigeria. Therefore, as an important part of the ecosystem, information on the species and distribution of terrestrial molluscs would provide reference material on malacological diversity of northern Nigeria. This study therefore focuses on the geographical distribution, habitats and species composition of terrestrial molluscs species as reflected by samples taken from terrestrial habitats in northern Nigeria.

Materials and methods

Study area

Sampling sites were spread across northern Nigeria (Longitude 8°-14°N; Latitude 3°-14°E). Northern Nigeria falls within the savanna ecoregion. The Guinea-savanna covers the north-central and part of the north-west; the Sudan savanna covers most part of the north-east and north- west. The Sahel savanna covers a small portion in the extreme north-east zone close to Lake Chad (Happold, 1987), Figure 1.

Study design

Using area sampling technique, a small-scaled grid map of northern Nigeria was used to determine potential collection sites for terrestrial molluscs, based on the different vegetation zones. Possible collection sites were determined on the basis of on-the-spot-assessment of

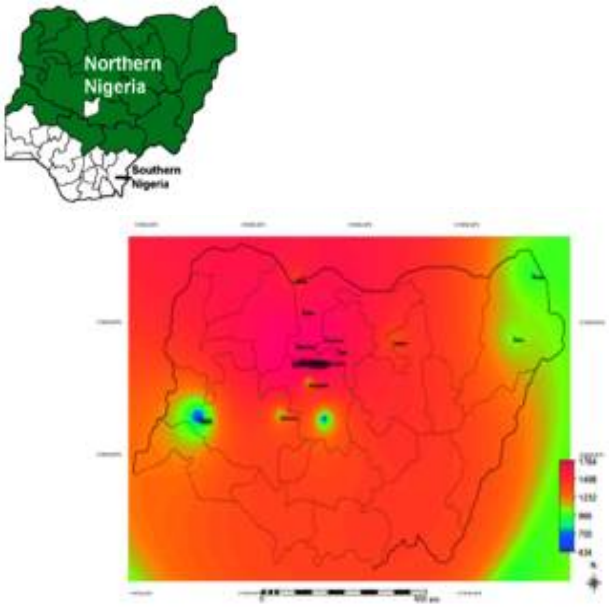

Figure 1. Digital elevation model of northern Nigeria.

Source: Nigeria Landsat1, 2001.

the potential sample areas. Molluscs were collected over a period of three years, during the wet and dry seasons. A 12.1 megapixel digital camera was used to take photographs of molluscs at the sites of collection and in the laboratory. Habitat factors such as vegetation, elevation and environmental observations (such as soil texture) were recorded.

Collection and analysis of soil samples

Soil samples from sites of collection of terrestrial snails were collected from depths of 0-5 cm in triplicate using an Auger and placed in the labelled polythene bags. Soil pH was measured in a 1:1 (soil: water) mixture (Kalisz and Powell, 2003). Soil samples were analyzed for extractable calcium in the laboratory of the National Research Institute for Chemical Technology Zaria, using Atomic Spectrophotometer (UNICAM 969).

Measurement and preservation of molluscs

Heights and breadths of the shells were measured with a sliding calliper. The number of whorls characteristic of each species' shell was counted and the direction of the spiral coil noted. All live and dead terrestrial snail shells were collected and preserved in labelled collection bottles containing 95% alcohol, and taken to the laboratory for further examination. The molluscs collected were identified using the taxonomic guides by Janus (1965), Burch (1989) and Barney (2000).

Statistical analysis

Linear regression analysis was used to determine the relationship (if any) between soil calcium and pH using Analyse-it v.2.14 (Analyse-it, version 2008). The data

for soil pH and calcium of where snails occurred were subjected to Pearson correlation coefficient.

Results

Six families of terrestrial molluscs were recorded in this study with the family Achatinidae being the most common and widely distributed (Figure 2). All the families except Achatinidae are represented by single species. Ten of the twelve species of terrestrial snails found in the study-area were indigenous species. The other two species, *Archachatina marginata* (Swanson, 1821) and *Acharchatina marginata suturalis*, were presumed to be introduced. With the exception of the achatinidae, the distribution of most of the families of the terrestrial gastropods was restricted to specific habitats (Table 1).

The only slug encountered in this study is of the family Veronicellidae. This slug was encountered in habitats with high humidity on the Jos Plateau (Jos Metropolis)

Table 1. Distribution, habitat preference and abundance of terrestrial mollusks in parts of northern Nigeria.

Family	Species	Plate	Abundance	Regional status	Vegetation zone	Habitat factor/Type
Veronicellidae	*Veronicella* sp.		+	Indigenous	NGS	Areas of high humidity and near to well-lit structures.
Subulinidae	*Lamellaxis*sp.		++	Indigenous	NGS to SuS	Very moist, high humic soil, forested areas.
Helicarionidae	Helicarionid*		+	Indigenous	NGS	Very moist, high humic soil. Forested areas.
Ariophantidae	*Macrochlamys*sp.		+	Indigenous	NGS to SuS	Areas of high humidity and vegetation.
Rhytididae	*Rhytida*sp.		+	Indigenous	NGS	Very moist, high humic soil. Forested areas.
Achatinidae	*Achatinaachatina*		+++	Indigenous	NGS to SuS	Dry to very moist savannas.
Achatinidae	*Achatinafulica*		+	Indigenous	NGS	Semi-dry to very moist, high humic soil to forested areas.
Achatinidae	*Limicolariaflammea*		+++	Indigenous	NGS to SuS	Dry to very moist savannas.
Achatinidae	*Limicolariakambeul*		++	Indigenous	NGS to SuS to ShS	Dry to very moist, high humic soil.
Achatinidae	*Limicolariaturris*		++	Indigenous	SuS	Dry to very moist, high humic soil.
Achatinidae	*Archachatinamargina ta*		+	Introduced	NGS	Very moist, high humic soil, protected areas (Farms).
Achatinidae	*Archachatinamargina tasuturalis*		+	Introduced	NGS	Very moist, high humic soil, protected areas (Farms).

Key: + = Rare (1-5 Snails); ++ =Uncommon (6-20Snails); +++ = Common (21Snails and above).*-Not species name (Unidentified helicarionid). NGS-Northern Guinea Savanna; SuS- Sudan Savanna; ShS- Sahel Savanna.

and shaded humic soils in parts of Zaria. This veronicellid slug exhibited nocturnal habits and appears to be restricted in its range of distribution. The soil texture at the sites of collection of terrestrial molluscs was mostly loamy. The soil calcium content of these sites varied from 1.44-2.52 Cmol/kg, with an average value of 1.98 (SD = 0.31) Cmol/kg and pH of 6.69 (SD = 0.39) 0.05 (Table 2). Terrestrial snails showed preference for soil calcium level of 1.75 to 2.00 Cmol/kg (Figure 3) with the median value expressed in Figure 4 and pH levels between 6.25 and 6.50 and 7.0 to 7.25 (Figure 5). The median value (50th Percentile) for soil pH is at 6.57 (Figure 6). There was a high positive correlation (*p*d"0.01; *r* = 0.93) between soil calcium and pH (Table 2).

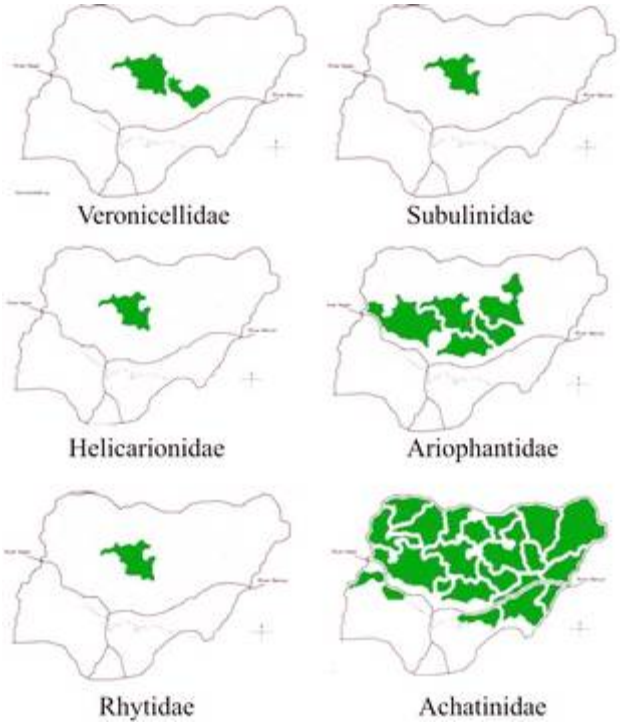

Figure 2. Distribution maps of the families of terrestrial molluscs in parts of northern Nigeria.

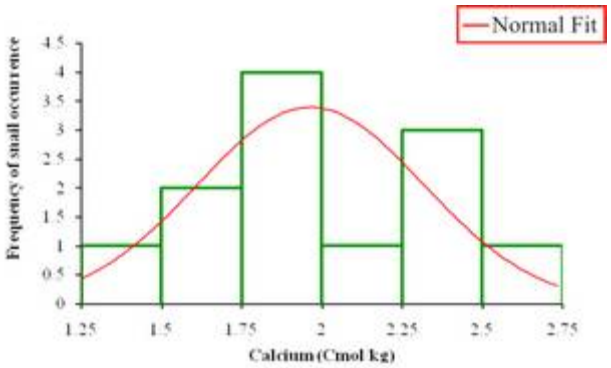

Figure 3: Frequency of occurrence of terrestrial molluscs at different calcium levels in parts of northern Nigeria.

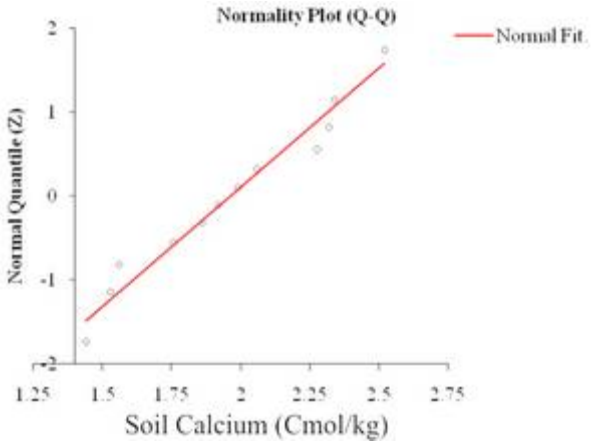

Figure 4: Normality Plot and variation in soil calcium of terrestrial molluscs in northern Nigeria.

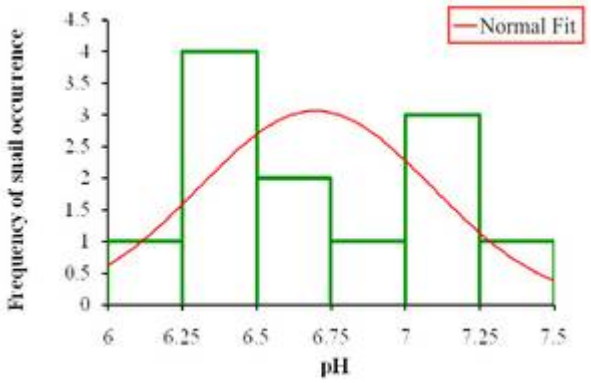

Figure 5: Frequency of occurrence of terrestrial molluscs at different pH levelsin northern Nigeria.

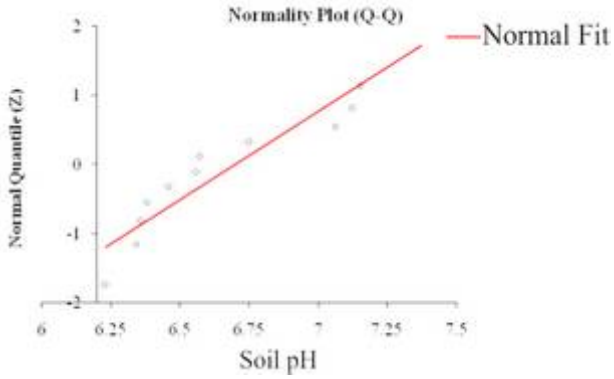

Figure 6: Normality Plot and variation in soil pH of terrestrial molluscs in northern Nigeria.

Table 2. Terrestrial mollusc species and mean calcium and pH values of soils in parts northern Nigeria.

Species	Mean (±S.E) Soil Calcium (Cmol/kg)	Mean (±S.E) Soil pH
Veronicella sp.	1.53 ± 0.01	6.38 ± 0.12
*Lamellaxis*sp.	1.56 ± 0.04	6.46 ± 0.07
Unidentified helicarionid	1.44 ± 0.02	6.23 ± 0.15
Macrochlamys sp.	2.32 ± 0.12	7.12 ± 0.26
*Rhytida*sp.	1.76 ± 0.10	6.36 ± 0.23
Achatina achatina	1.99 ± 0.56	6.75 ± 0.44
Achatina fulica	2.28 ± 0.45	7.15 ± 0.11
Limicolaria flammea	2.34 ± 0.78	7.06 ± 0.22
Limicolaria kambeul	2.52 ± 0.69	7.41 ± 0.34
Limicolaria turris	2.06 ± 0.36	6.56 ± 0.56
Archachatina marginata	1.86 ± 0.19	6.34 ± 0.07
Archachatina marginata suturalis	1.92 ± 0.63	6.57 ± 0.03

Discussion

Of the twelve (12) species recorded, *Archachatina marginata* and a subspecies *A. m. saturalis* are native snails of southern Nigeria that have been introduced to northern Nigeria. With the exception of the family Achatinidae, all the other families were represented by single species. The pattern of distribution of terrestrial snails in northern Nigeria is ubiquitous and restricted in some cases. In this study moisture availability and lush vegetation could be considered as important factors in their distribution. The number of species and availability of snails decreased as the environment got drier northwards of the fringes of the sudano-sahel regions.In the drier parts of the study-area towards the Sahel, the distribution of achatine snails along water course and receded parts of the Lake Chad could be a strategy by the snails to maximise active feeding regime and reduce aestivation period. The presence of empty shells of terrestrial molluscs observed in some parts of the study area could be an indication of habitat loss due to environmental degradation which prolongs the mollusc aestivation period and eventually results in death of the molluscs. Many achatinids are able to secrete a protective epiphragm in order to temporarily close the shell aperture, which for species living in the drier parts of Africa is considered of great survival value (Raut and Barker, 2002).

The Achatinidae are the dominant land snails and inhabit most part of the study-area. Pilsbry (1919) considered the natural area of distribution of the genera *Achatina* and *Archachatina* to be West Africa, whose species are distributed in less humid areas (Hodasi, 1984). The *Archachatina marginata* in northern Nigeria are non-native and purposely introduced and reared in farms, protected areas and botanical gardens for economic and research reasons. The subspecies *A. m. suturalis* encountered near these habitats were likely to be escapees from poorly managed snail farms.In this study, the genus *Limicolaria* is the dominant taxon of the family Achatinidae, with *L. flammea* being the most common. Passive dispersal agents (such as human activities involving transportation of old tyres, fuel wood, car scraps etc with the snail attached) could be responsible for the high dispersal of *L. flammea* in the region. *Limicolaria* are reported as common in different terrestrial habitats in West Africa and are regarded as 'tropical' (Crowley and Pain, 1970). The genera *Achatina* and *Limicolaria* can cause extensive damage to agricultural crops and therefore are pests (Crowley and Pain, 1970; Hunter and Runman, 1972; Mead and Palcy, 1992), and as vectors and intermediate hosts to different digeneans (Purchon, 1968; Odei, 1966; Bourgat *et al* 1975; Soulsby, 1982; Marquardt and Demaree, 1985; Sowemimo and Asaolu, 2004; Gadzama and Ogiugo, 2008).

The families Subulinidae and Arionphantidae represented by *Lamellaxis* sp. and *Macrochlamys* sp. Respectively are damp soil snails with presumed narrow tolerance for moisture. Subulinidaeis a family of elongate terrestrial pulmonate gastropod snails which is widespread throughout most tropical and warm temperate regions. Wu *et al* (2007) reported *Lamellaxis gracilis* as abundant snails commonly found under shrubs. Too little is known of the pest potential of the subulinids; they are rarely mentioned in the pest literature (Cowie *et al* 2009). *Macrochlamy sindica* is believe to represent a potentially serious threat as an invasive pest species which could have negative effects on agriculture, natural ecosystems, human health or commerce (Cowie *et al* 2009). Oke and Alohan (2006) reported the occurrence of species of the families Veronicellidae, Subulinidae and Achatinidae in the tropical rainforest of Okomu National Park in Edo State, Nigeria, and among the dominant taxonomic groups in tropical rainforest in south-west Nigeria (Oke and Chokor, 2009).

The veronicellid slug's nocturnal habit and preference for highly humid areas could be an adaptative feature to avoid the high temperatures during the day and the consequent water loss. This family of herbivorous slugs is widely distributed in tropical regions of South America, Southern Asia, Africa, Madagascar, and Indian Ocean Islands (Herbert and Kilburn, 2004).Oke and Chokor (2009) also reported a single species of the family Veronicellidae in the tropical rainforest of Edo State in south-west Nigeria. Slugs within this family Veronicellidae have been found to harbour several nematode parasites including *Angiostrongy luscantonensis* (rat lungworm), *A. costaricensis*, and *A. malaysiensis* (USDA-APHIS, 2010). The distribution of the helicarionid snail is highly restricted to humid forests of the northern Guinea Savanna (Kagoro Forest, Kaduna State). The Helicarionidae is a family of air-breathing land snails or semi-slugs, terrestrial pulmonate gastropod

molluscs in the order Stylommatophora (Zipcode Zoo.com). The family is widely distributed globally and species are both ground-dwelling and arboreal. The Helicarionidae serve as a good example of how snails could gradually evolve into slugs (Rudman, 2006). Hollingsworth *et al* (2007) reported the helicarionid, *Parmarion martensi,* as a potential vector for human angiostrongyliasis. The snail *Rhytida* sp. (Rhytididae) occurred in the same habitat as the helicarionid and was found on wide leaves of lushly herbaceous trees in the humid forest. During the day, this snail remained inactive and characteristically enveloped itself in numerous small white bubbles which may be repellent to potential intruders. The Rhytididae is a family of medium-sized predatory air-breathing land snails, carnivorous terrestrial pulmonate gastropod molluscs (ZipcodeZoo.com).

Two important soil factors, soil calcium and pH, were considered in this study. The soil calcium range (1.44-2.52 Cmol/kg) obtained in this study may be considered adequate for growth and shell development of terrestrial molluscs. The high significance between sites where snails were collected showed preference for calcium-rich soils by the snails. Soil chemistry is known to influence the occurrence of terrestrial snails (Kerney *et al* 1983). Molluscs are reported to occur in soil with calcium range of 0.8-10 g/kg (Kappes *et al* 2006). Tompa (1980) reported that insoluble salt of calcium carbonate was one of the major steps in colonization of land by various groups of gastropods. Mand *et al* (2000) reported on the unusual quantity of calcium required by animals such as crustaceans, molluscs and birds at certain stages of their life. Calcium in the diet of terrestrial gastropods is an essential nutrient for growth and reproduction and construction of the shell (Boycott, 1934; Tompa and Wilbur, 1977). The high positive correlation ($r = 0.93$) between soil calcium and pH could be because they jointly influence the occurrence of molluscs. Therefore it could be that terrestrial molluscs in this study showed preference to these two soil factors aside moisture. Hotopp (2002), Martin and Sommer (2004) and Kappes *et al* (2006) reported soil calcium to be positively correlated to pH and snail abundance. The soil pH range of 6.23 to 7.41 obtained in this study is within the range of 6.7 to 7.8 for terrestrial molluscs as reported by Kappes *et al* (2006) and the median value indicates preference of terrestrial mollusks to alkaline soil condition. Therefore soil pH level can be used as an important index in determining the presence and absence of terrestrial molluscs in the study area. The pH of soil is reported to affect snail density and diversity (Wareborn, 1992; Gardenfors *et al* 1995; Martin and Sommer, 2004). The preference of humic soil by the terrestrial snails in this study could be attributed to its prolonged moisture retention capacity and relatively lush vegetation it supports.

In conclusion, this study has shown that the terrestrial ecosystems in northern Nigeria support a highly diversified malacofauna of ecological and probably of public health significance. Soil pH and calcium are important factors in the distribution of terrestrial molluscs. The patchy presence of some of the molluscs was due mainly to level of precipitation and moisture retention of areas of occurrence. *Limicolaria flammea* is the most common terrestrial snail in northern Nigeria. Although the distributional range of *Archachatina* snails is restricted, their invasive nature could be a threat to the relatively smaller native *Achatina* and *Limicolaria* snails.

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