Estimates of home range sizes of *Arvicanthis niloticus* Desmarest, 1822 (Muridae) in savannah fields near Kano, Nigeria

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Abstract

Determination of rodent home range (HR) is invaluable for characterizing population distribution and strategies for accessing food, mate and nest sites, as well as, dispersal into new fields. The present study, in savannah fallow fields near Kano, Nigeria, was aimed at estimating HR sizes of *Arvicanthis niloticus*, a species widespread in much of Africa. By Capture-Mark-Recapture (CMR) in a five to six-day/month sessions on replicate grids during 1990-1992; and 25 years later followed by a one year, quarterly, appraisal surveillance during 2015-2016, the movement patterns of *A. niloticus* were analyzed by means of Minimum Convex Polygon (MCP) calculations. With GLM ANOVA, comparisons between sexes, seasons and periods of study were made. Further HR comparisons were made with Kruskal-Wallis tests. Predictors (year of study, sex of the rodent and season) which contributed to significant differences in HR sizes were also identified with stepwise regression. Overall, ANOVA results showed that sex had significant effect (p<0.05) on HR, larger (1,036 m^2) mean HR sizes than that of females (850 m^2). Seasonal differences were also significant (p<0.05). Kruskal-Wallis tests also indicated significant (p<0.05) differences between sexes, seasons and age groups, being higher in males than females; greater in dry than in rainy season; but marginally greater in adults than juveniles (p=0.056). Generally, HR size values for 2015-2016, the second segment of the study, had shown similar patterns as those of the 1990s, again with significant (p<0.05) differences between sexes, seasons, and between sexes within seasons. However, overall HR values in 2015-2016 were lower than those of 1990-1992 composite year. From the forgoing, we may conclude that though long-term temporal lapse and ensuing environmental degradation may reduce HR sizes in *A. niloticus*, the general patterns of age-sex and seasonally related differences do not change.

Keywords: Africa; grassfields; home range; Nile rat; movement; rodents.

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Introduction

One of the most enduring and often cited definition of mammalian home range (HR) is that of Burt (1943), who described it as that area traversed during the normal activities of feeding, mating, and caring for young. This definition specifically excludes occasional excursions outside the area of regular activities. The determination of area of regular use, both conceptually and through computation, has been sought by many workers, e. g., (Frafjord and Prestrud, 1992; Michener, 1979; Powell, 2000; Pulliainen,1984). HR determination is significant in contributing information on a species, and its surroundings, including its distribution and accessibility to resources and foraging sites, nest and mate locations, among other movement activities (Powell, 2000). HR data may also yield information on interactions amongst individual members of the population, and perhaps certain aspects and dynamics of species larger community. For small mammal pests or opportunistic pest species such as *A. niloticus* (Rabiu and Rose, 1997; 2004), which has also been indicted as a probable rodent vector of schistosomiasis, and possibly some other microbial diseases (Duplantier and Sene, 2000), an understanding of HR can help in planning control management efforts.

Across tropical Africa the genus Arvicanthis Lesson 1842 (Muridae), has about seven species, and possibly additional ones (Kingdon *et al* 2013). The genus is fairly common across its distribution, with species in eastern Africa (Delany and Monro, 1985; Hoffman *et al* 2006; Massawe *et al* 2007), the lowlands of Ethiopia (Chekol *et al* 2012); and in western Africa (Poulet and Poupon, 1978; Rabiu and Fisher,1989; Rabiu and Rose, 1997; 2004). In the Savanna and Sahel of West Africa, A. niloticus (Desmarest, 1822) is probably a complex of three sibling species, namely, *A. ansorggei, A. rufinus* and *A. niloticus* (Kingdon *et al* 2013). The present study is concerned with the latter species, i.e., *A. niloticus*, a resident of grassy habitats and farm fields of the Sudan and Sahel savannah and derived savannah of Nigeria.

Literature on the movement and spatial activities of *A. niloticus* is limited, with much of what is known contributed from eastern Africa (Hoffman *et al* 2006), hence the need for the present data from western part of Africa. Numerous reports on patterns of movement

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activities in *A. niloticus* have revealed a largely diurnal routine (Rabiu and Fisher, 1989; Sen-zota, 1990). Also, larger HR size in males than females has been observed by workers, including, Delany and Monro (1985), Packer (1983), Senzota (1990) and others. HR characterization is commonly examined in terms of area, but some investigators have also adopted a linear or distance approach (e.g., Delany and Monro, 1985; Szacki and Liro, 1991). In general, HR in rodents may be affected by age-sex class, body mass, reproductive period and availability of food resources (Wood *et al* 2010).

The present study sought estimates of HR in *A. niloticus*; verification of any age-sex class (male, female, juvenile) differences; as well as, to test the hypothesis of no significant effects of seasons on HR sizes in the natural savannah fields near Kano, Nigeria, West Africa.

Materials and methods

Study area

This was south of the intersection of the Kano-Zaria and Bagauda-Jos Highways, and included fallow, uncultivated, fields south of Bagauda, 11⁰41′N; 8⁰21′E; North of Bagauda, 11⁰43′N; 8⁰24′E, approximately). Within 50 km to the east and south-east were scattered government housing and small subsistence plots that were intensely farmed. Another sector was to the north of Gwarmai, (11⁰33′N; 8⁰16′N and 11⁰33′N; 8⁰19′E, approximately). See Figure 1.

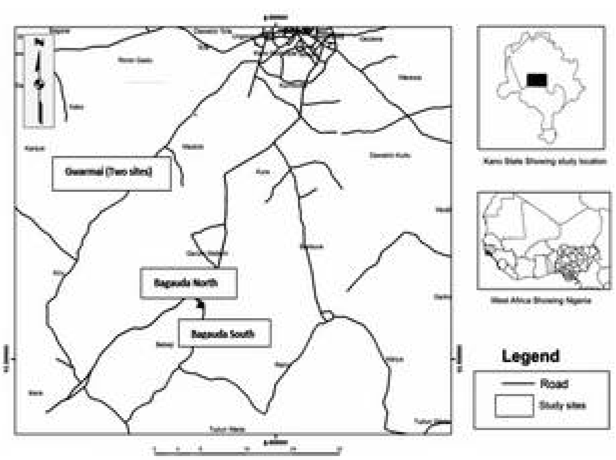

Figure 1. Trapping sites in old fallow fields at Bagauda and Gwarmai, south of Kano, Nigeria.

Monthly mean summer (March to September) temperatures sometimes exceed 30°C and annual rainfall averages about 980 mm^3/year. Precipitation is the monsoon, seasonal type, beginning in April and sometimes lasting until early October. In years of drought, an infrequent but recurring feature of this region, the onset of rains may be as late as June (Figures 2a and 2b). Rabiu and Rose (2004) note rain-fed food crops that included sorghum and millet, and cash crops, typically cowpeas, peanuts, sesame, and cotton, are grown.

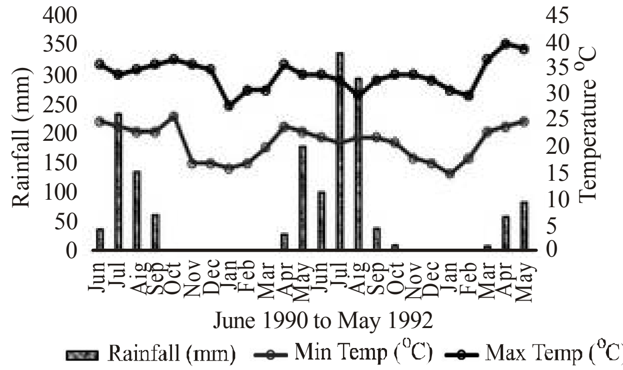

Figure 2a. Mean monthly rainfall and temperature (maximum and minimum) data from Kadawa, near the study-area during the first segment of study (June 1990 to May 1992).

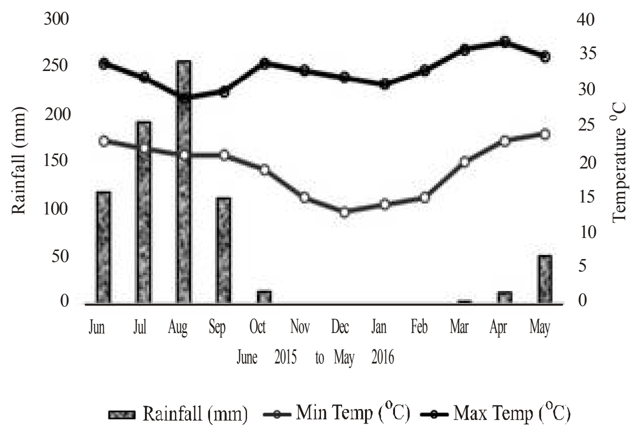

Figure 2b. Mean monthly rainfall and temperature (maximum and minimum) data from Kadawa, near the study-area during the second segment of study (June 2015 to May 2016).

Trapping

There was a wire fence in Bagauda South that provided limited protection from human and livestock activities. Here, trapping grids had been permanent (i.e., maintained throughout the trapping period). In other grids at Gwarmai we suffered trap losses and frequent disruptions on account of vandalism. Each of the grids had parallel trap lines, 10 m or 15 m apart, with at least 90 trap stations spaced at 15 m or 10 m intervals, placed wherever concealment was possible, and chances of loss minimal. Animal movement records by Capture-Mark-Recapture (CMR) were recorded, monthly, during June 1990 to May 1992. The trap-make was modified

Fitch type (Rose, 1994), which were more suitable for our purpose than Longworth traps or other commercial makes which tend to exclude Nile rats >140 g (Rabiu and Fisher, 1989). Trapping was conducted monthly for four days, with traps checked in the early morning and at dusk. Throughout much of the study, traps were covered with cardboards or thick tuft of grass to protect the rodents from rain, heat, or cold. It was necessary to change the cardboards frequently due to degradation by termites and sheltering ants, but rain was not a serious problem as soggy cardboards quickly dried up soon after the rains. Captured animals were given numbered ear tags, and information was recorded for sex, weight, and coordinates of capture on the grid. Minimum body weight of 60 g was used to define maturity for both sexes, and those weighing less were considered juveniles. Nestlings and younger animals that were confined to nests or lingered around burrows were not considered trappable, and if they were trapped, were allowed escape by the mesh of the trap tunnel. Only animals with a minimum of four recaptures were considered for Minimum Convex Polygon (MCP) calculations.

The protocol described above was during June 1990 to May 1992 on regular monthly basis, but on account of the lapse of time, we decided that the data, not yet published, could be enhanced with some new substantiation, and perhaps help check the effects of time and physical changes in the habitat over 25 years. Hence, we repeated the effort but, this time over a period of only one year, June 2015 to May 2016, and on a quarterly basis.

Estimates of home range sizes

A half distance between traps (= 5 m) was added to each end of the distance between the most widely separated capture locations. After log transformation, we estimated the area of HR using MCP. We programmed grid capture coordinates into MATLAB-Version R2013b software for the calculations. Only animals that met the minimum of four capture observations were considered for the analysis. Indeed, greater than three capture points were needed to establish a polygon for the activity of any animal.

By simple statistics, we compared the mean values of HR area sizes between the sexes during both 1990-1992 composite year and the 2015-2016 single year. We also used the GLM model of analysis of variance to make several comparisons between sexes, seasons and periods of study. Further statistical analysis, again using GLM ANOVA was used to compare HR sizes and test the effects of sex, season and the differing periods of study. A non-parametric statistic, the Kruskal-Wallis test was deployed to further check comparisons of HR sizes between age-sex classes, and between seasons. The test was chosen because it uses the median rank of the data values rather than the actual data values for the analysis, with the hypothesis Ho: the population medians are all equal. Stepwise regression was considered to help identify the predictors (year of study, sex of the animal and season) which contributed to significant differences in HR area sizes.

Results

Estimates of home range sizes

Mean annual HR area for composite year 1990-1992, for *A. niloticus* males (1067 m^2, SE 21 m^2) was greater than that of females (894 m^2, SE14 m^2). Monthly means of HR sizes for male *A. niloticus* (Figure 3a) were greater during the dry months of November to April (dry season mean HR area of 1224 m^2 SE 34 m^2) than during the rainy months of May to October (rainy season mean home HR of 990 m^2, SE 22 m^2). Differences in female mean HR area were not as dramatic between the seasons, but they too had significantly larger coverage areas in the dry months (943 m^2, SE23 m^2) than in rainy months (863 m^2, SE17 m^2). Notwithstanding the seasonal contrast, females generally use similar areas throughout the year but males markedly increase their HR in the dry season, then shrink during the rains (Figure 3a). The verification effort during 2015-2016 were in the same sampling sites as for the composite year 1990-1992. The results showed essentially the same pattern as the older data, that is, larger HR areas during the dry season than during the rains; and greater HR sizes for males than females, regardless of season (Figure 3b).

However, the overall HR size values were lower during 2015-2016 (923.00 m^2 mean for all animals) than in composite 1990-1992 year (1,018.50 m^2 mean for all animals). It should be stressed that the number of individuals used in statistical evaluations were those that met the minimum of four recaptures, otherwise the sample sizes were a lot larger. By individual sexes, the HR sizes for both females and males showed significant seasonal differences, greater HR sizes during the dry season than in rain season, as was the case for seasonal differences during the composite year 1990-1992.

The first annual quarter of the verification study, June-August, 2015, was the core rain period with mean HR size for females of 751 m^2, compared to over 860 m^2 during 1990-1992, a marginally significant difference (p = 0.056) by the GLM model of ANOVA, chosen for its robustness to differing sample sizes. The mean HR sizes during the months of the second and third quarters of 2015-2016, i.e. September through February, compared to those of the same months in the composite year 1990-1992, were significantly different ($p<0.05$). HR size for males in 2015-2016, with highest mean value being slightly over 1,200 m^2 during the third quarter (December to February), was significantly lower ($p<0.05$) than the mean for the same period during the composite year of 1990-1992. As with the 1990-1992 study, seasonal differences in mean HR sizes during 2015-2016 were generally more pronounced in males than in females. See Figures 3a and 3b.

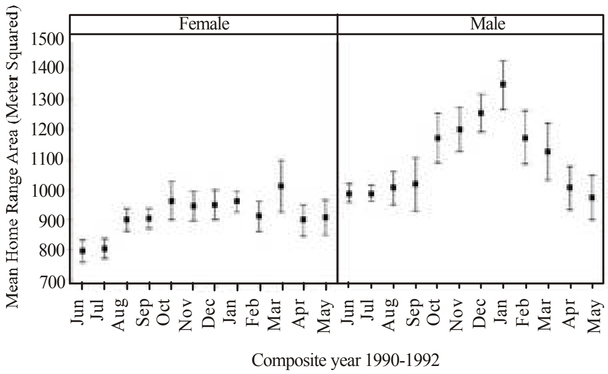

Figure 3a. Mean monthly and SE home range area in m² for both sexes of *A. niloticus* from four grids during a composite year (June 1990-May 1992), near Kano, Nigeria.

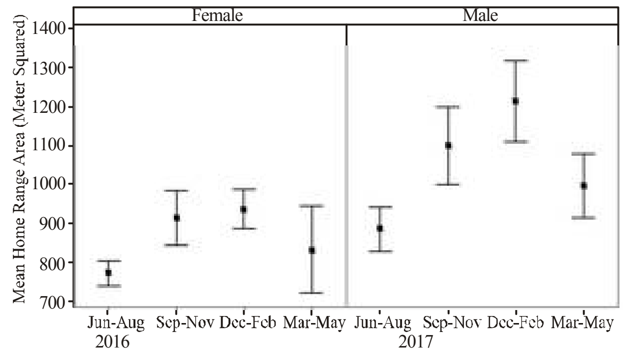

Figure 3b. Mean quarterly and SE home range area in m² for both sexes of *A. niloticus* from four grids (same ones as in Fig. 1a) during June 2015-May 2016, near Kano, Nigeria. This data was collected for the purpose of corroboration of, and comparison to, data in Figure 2a above, on account of time lapse.

During the composite year 1990-1992, the mean HR area of males was significantly larger than for females, H = 34.71, $p<0.05$ (Table 1a). Further, HR sizes were larger in the dry season than in the rainy season (H = 20.93, $p<0.05$), and marginally larger for all adults than for juveniles as a whole (H = 3.78, $p<0.05$). Additional comparisons are given in Table 1a.

By comparison, Kruskal-Wallis tests for 2015-2016 median HR sizes showed generally lower values than those of 1990-1992 composite year, but patterns of age-sex class and seasonal differences were the same between the two studies (Tables 1a and 1b); and again, males had consistently significantly larger HR sizes than females (dry season, 980 m² *vs.* rain season, 860 m²; males, 950 m² *vs* females, 825 m²; males in dry season, 1020 m² *vs.* males in rain season, 907 m²). Interestingly, the actual HR sizes between adults and juveniles; between the 1990-1992 and 2015-2016 studies, were only marginally significant statistical differences.

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All three factors in GLM analysis, namely period of study (1990-1992; 2015-2016), sex (male, female) and season (rain, dry) had significant effect on HR area sizes (Table 2). Similarly, the factors in GLM, used as predictors in stepwise selection, showed that each made significant contribution to the differences in HR area sizes (Table 3).

Table 1a. Kruskal-Wallis Test (adjusted for ties) for significant differences in mean home range sizes (m²) in *A. niloticus* between the sexes, seasons, and age classes (of individuals with greater than four recaptures) during composite year 1990-1992 from grids near Kano, Nigeria.

Comparisons	N	Mean HR size (m²)	K-W Test (*H*)	*df*	*p*
Female vs.	125	850.00	34.71	1	<0.05
Male	117	1,036.00			
Dry Season vs.	87	1,020.00	20.93	1	<0.05
Rain Season	155	900.00			
Adults vs.	198	950.00	3.78	1	=0.05
Juveniles	44	875.00			
Males in Rainy vs.	78	950.00	22.49	1	<0.05
Dry Season	30	1,235.00			
Females in Rainy vs.	71	930.00	9.96	1	<0.05
Dry Season	54	810.00			
Males vs. Fem. in Rainy	78	950.00	18.70	1	<0.05
Season	71	810.00			
Males vs.	30	1,235.00	27.02	1	<0.05
Fem. in Dry Season	54	930.00			

Table 1b. Kruskal-Wallis Test (adjusted for ties) for significant differences in mean home range sizes (m^2) in *A. niloticus* between the sexes, seasons, and age classes during June, 2015-May, 2016 in grids near Kano, Nigeria.

Comparisons	N	Mean HR Size (m^2)	K-W Test (*H*)	*df*	*p*
Female	55	825	33.58	1	<0.05
Male	53	950			
Dry Season	23	980	29.31	1	<0.05
Rainy Season	85	860			
Adult	73	900	20.65	1	>0.05
Juvenile	35	850			
Males in Dry season vs.	11	1,020	3.50	1	>0.05
Rain Seasons	42	920			
Females in Dry	12	900	6.66	1	<0.05
vs. Rain Seasons	43	800			
Females vs. Males in Dry	13	900	7.66	1	<0.05
Season	11	1,020			
Females vs. Males in Rain	12	800	7.90	1	<0.05
Season	11	920			

Table 2. Analysis of Variance (GLM) for the effect of study period (1990-1990; 2015-2016).

Source	*df*	Adj SS	Adj MS	*f*	*p*
Period (1990-1992; 2015-2016)	1	452002	452002	11.86	0.001
Sex (Males; Females)	1	1324883	1324883	34.76	0.000
Season (Dry; Rain)	1	1868137	1868137	49.01	0.000
Error	425	16198329	38114		

Sex (males; females); and season (dry; rain) on the mean home range sizes of *A. niloticus* in grids near Kano, Nigeria. Age effect (adults; juvenile) was excluded because they juveniles were not present year round.

Table 3. Coefficients and *p* for Stepwise Selection of (1), study periods (1990-1992; 2015-2016); Sex (males; females); and Season (rain; dry).

Terms	Step 1		Step 2		Step 3	
	Coeff	*p*	Coeff	*p*	Coeff	*p*
Constant	967.9		970.00		966.34	
Season	63.4	0.000	65.32	0.000	67.82	0.000
Sex			-55.45	0.000	-55.63	0.000
Study period					32.82	0.001
S		205.125		197.700		195.227
R-sq(adj)		8.18%		14.70%		16.83%
R-sq(pred)		7.49%		13.86%		15.80%

Predictors for contribution to differences in home range area sizes in *A. niloticus* from grids near Kano, Nigeria. Values for alpha were set at 0.05 instead of the 0.15 default for this statistics. Regression, R^2 values are also given. Juvenile rodents were excluded because they were not present year round.

Therefore, we think that there was an obvious decline in home area sizes from the time of the study in 1990-1992 to that of 2015-2016; as well as, consistently, during both studies, larger HR areas during the dry season compared to rainy season; and larger HR areas in males than females; and in adults more than in juveniles.

Discussion

The MCP method of HR analysis

As noted earlier, we used the MCP method for computing HR areas, which suits our CMR data. The CMR data is lacking in numerous multiple capture records as would be available for radiotelemetry sampling records. Even so, we used the preferred, though really non-standardized 95% method, to help achieve two things. One, douse concerns for occasional sallies (Burt, 1943); and, two, for accurate determination of areas of greater activity (core-activity) area use (Michener, 1979), who argued that the core activity area, where sought, is best determined at the 95% method. Regardless which amount of data one is prepared to use, 100% or 95% (Powell, 2000) contends there is no existing standard on whether to include the 100% or the lesser record (95%) into the HR of those places the animal rarely visits or, simply just explored only once. The true HR, many workers argue, should exclude the rarely visited sites by the animals, i.e., have expressed the preference of the 95% data, noted earlier. Besides, it should be noted that HR boundaries and areas are probably imprecise (Powell, 2000) on account of certain reasons, including the probable imprecise nature of the areas and boundaries to the animal themselves. Nonetheless, we appreciate the preferred use of 95% data method employed by other investigators to address the aforementioned concerns (e.g., Burt, 1943; Michener, 1979).

In our situation, the use of 95% of the recapture data points meant shedding some data. Still, we had enough recapture points left to allow for both parametric and non-parametric tests. Therefore, from this study, we found the MCP method reasonable to inform ecologists on HR area sizes for small mammals. Since we had essentially two sets of data from 1990-1992 and 2015-2016, we were persuaded by arguments that the MCP method does fairly well, and is reliable, for comparing HR estimates made from different studies (Harris *et al* 1990; White and Garrott (1990).

Sex differences in home range sizes

Home range area sizes were always greater in males than in females. This evidence of higher range areas was also documented in studies of the species in eastern Africa (Delaney and Monro, 1985; Hoffmann *et al* 2006) notwithstanding the possibility of taxonomic differences between the east and West African populations, and of the differences in rains and breeding patterns. Significant difference in HR area sizes between male and females was also reported in Nowak (1999) where male's HR size measured from 1,400 to 2,750 m^2, and females' from 600 to 950 m^2, were, for the males, larger than in the present study. As with Delany and Monro (1985) we also observed linear and across trap lines movements by individuals of both sexes that appear to represent somewhat permanent shifts in warren residency.

Seasonal differences in home range sizes

For both male and female *A. niloticus*, the seasonal differences in HR areas between dry and wet seasons were statistically significant. The generally smaller range areas during the rainy season, which is also the breeding season (Rabiu and Rose, 1997; 2004) may be a result of greater reproductive demands imposed by the need to manage nests and or possibly a reflection of resource abundance in close proximity of the warrens. There is also the possibility of restricted movement due to occasional flooding caused by excessive rainfall, rendering the runways waterlogged. For both segments of the present work, the 1990-1992 and 2015-2016 studies, the reproductive season ends in September-October (Rabiu and Rose, 1997; 2004) a time when population sizes were largest. Delany and Monro (1985) and Hoffmann *et al* (2006) noted that for *A. niloticus* in eastern Africa, range estimates tend to be low when population sizes are at high. In the present study, July and August, were breeding months (Rabiu and Rose, 1997), when range sizes were lowest, in fact lower than that of September-October period, perhaps because of heavy rains and waterlogged conditions that may have restricted movements. The period during November-March (dry months) was a time when the surrounding vegetation, and by extension rodent foods, become scanty, further diminished by grazing livestock that were roaming the general area. This was also the period when the range area size (average 1,020 m^2) were at high, expectedly, since the rodents must venture further out of their home base warrens or nests for dietary needs and other resources.

The 2015-2016 HR size patterns of age, sex, and seasonal difference in *A. niloticus* HR were essentially the same as the patterns of 1990-1992, i.e., greater HR sizes in males than females; greater HR sizes in adults than juveniles; greater HR sizes during the dry season than in rainy season. This finding with respect to *A. niloticus* was not only consistent with other studies of *A. niloticus* from elsewhere (Hoffmann *et al* 2006), it does hold true across other murid taxa (Odhiambo *et al* 2005; Wood *et al* 2010). Notwithstanding the similarities of HR size patterns between the 1990-1992 and 2015-2016 segments of this study, there were statistically significant differences with respect to HR age, sex, and seasonal values. The lapse of over 20 years between the two segments of the present study has meant increased degradation of environment, reduced vegetation, poorer habitat, and possibly substantial loss of cover (Aigbe and Oluku, 2012; Macaulay, 2014) which probably had an impact on *A. niloticus* and possibly other species. These were events that might also be linked to climate changes (Muhammed *et al* 2015).

The Nile rat, *A. niloticus* is a rainy season breeder in northern Nigeria, a time when adult males move greater distances and cover larger areas than either females or juveniles, notwithstanding overlaps in their HR sizes. However, during the non-breeding season, both sexes travel even longer distances and visit larger areas than in the wet season, perhaps in response to lower levels of food resources in their former area of greatest use. Substantial passage of time with consequent degradative changes in local habitat has caused generally reduced HR sizes for *A. niloticus*, while keeping patterns of age, sex and seasonal differences unchanged.

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