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Georgewill, I, Akani, GC, Luiselli, L, Petrozzi, F, Dendi, D, Ugbomeh, AP, Fa, JE and Onuegbu, GC (2022) Determining the composition and structure of antelope communities in three study sites within the Niger Delta (Nigeria) based on bushmeat market data. *Tropical Ecology*, 63 (1). pp. 145-150. ISSN 0564-3295

Downloaded from: <https://e-space.mmu.ac.uk/628227/>

Version: Accepted Version

Publisher: Springer Nature

DOI: <https://doi.org/10.1007/s42965-021-00180-3>

Please cite the published version

<https://e-space.mmu.ac.uk>

1 **Composition and structure of the antelope communities at three study**
2 **areas of the Niger Delta (Nigeria) based on bushmeat market data.**

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18 **Running Head:** Niger Delta antelopes

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23 **Keywords** : Antelopes, bushmeat market, conservation, ethnozoology, Rivers State.

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INTRODUCTION

26 Nigeria, currently the largest, richest and most densely populated country in Africa, by the
27 early 1990s was already as densely populated as Western Europe with an average of 130
28 people per km² (Janus and Jaeger, 2011). Since several decades, the rapidly growing
29 population was placing enormous pressures on the country's natural resource base, and most
30 of the formerly extensive natural forest and savanna habitats have been degraded or destroyed
31 by the expansion of agriculture, excessive wood-cutting to supply timber and fuelwood, and
32 overgrazing of grasslands by livestock (e.g., Osuide, 1990). In addition to widespread
33 degradation and destruction of natural habitats, wildlife has suffered severely from
34 uncontrolled hunting for bushmeat (e.g., Martin, 1983; Anadu et al., 1988; Fa et al., 2006). In
35 southern Nigeria, antelopes have always been purposely targeted among the best target of
36 hunting for bushmeat because of they are highly valued as tasteful food by local communities
37 (Luiselli et al., 2019). Thus, their wild populations may have been possibly depleted (e.g.,
38 Blench, 2007; Luiselli et al., 2015; Petrozzi et al., 2015), despite no quantitative study has
39 ever been performed in order to evaluate the demographic characteristics and the structure of
40 Nigerian antelope communities.

41 In order to fill the above-mentioned gap in knowledge, in this paper we analyze the
42 antelope fauna composition at three distinct study stations in the southern Niger Delta,
43 characterized by lowland forests and forest-plantation mosaic landscapes. Because of the
44 difficulty in studying the abundance of these ungulates in the swampy forests, we use data from
45 three markets to evaluate the relative abundance of the various species and the diversity metrics
46 of the antelope community. In addition, we also analyze the sex ratio of these populations and
47 the effect of season on the apparent abundance of the various species.

48 MATERIALS AND METHODS

49 The present study was carried out by monitoring three bushmeat markets: Omagwa
50 (04°59'04"N, 06°55'05"E), Oyigbo (04°53'32"N, 07°10'0"E) and Mbiama (05°03'0"N,
51 06°27'0"E) in the Rivers State, southern Nigeria (Fig. 1). Rivers State, with over 5 million
52 inhabitants and more than 630 persons/km² density (Rivers State Government, 2019), has
53 undergone, during the last 30 years, a strong agricultural and industrial expansion that caused
54 severe fragmentation of the existing forests (Niger Delta Environmental Survey, 1998; Akani,
55 2008). The study area's climate is characterized by a long rainy season from April through to
56 the end of September.

57 The three study stations were chosen because they represent localities in which
58 hunting, alongside traditional agriculture, provide the basis of the local rural population's
59 economy. The three localities differed in terms of vegetation cover and human population
60 density (Hansen et al., 2013; Center for International Earth Science Information Network -
61 CIESIN - Columbia University, 2017); the latter being significantly higher in Mbiama than in
62 the other localities (Table S1). Local hunters live in bushland and forest patches often <7 km
63 away from the market. They regularly supply a variety of animal carcasses for their sale.

64 The three bushmeat markets were surveyed during both the dry season (December
65 2017- March 2018) and the wet season (May 2018- August 2018). Surveying effort was
66 identical in the three monitored markets: each market was visited (between 7.00-11.00am)
67 three times per week during eight months (48 daily visits in each season), and all animal
68 carcasses on sale, including ungulates, were counted on each sampling day. We counted and
69 inspected the various available carcasses as hunters dropped them with the bushmeat traders.

70 We used contingency table χ^2 tests to investigate differences among the observed
71 number of individual animals by sex, season, and market. Saturation curves were built for

72 each market site with 95 % confidence intervals. Bootstrap analysis was applied to generate
73 upper and lower confidence intervals of all indices, with 9,999 random samples, each with
74 the same total number of individuals as in each original sample being generated (Harper
75 1999). Inter-specific differences in the means of a set of morphometric characteristics (Table
76 S2) were assessed by Student t-test.

77 In order to compare community structure data collected in this study, we used the
78 following diversity metrics (Magurran, 1988): (a) Species richness, the total number of
79 species recorded into each habitat type; (b) Dominance: $D = 1 - \text{Simpson index}$; (c) Simpson
80 index: $S = 1 - D$; (d) Shannon-Wiener H' index (Shannon & Weaver, 1963; (e) Evenness,
81 calculated using Pielou's formula (Magurran, 1988); (f) Chao 1, the number of species
82 predicted to be present at each study area given the sample observed (Hughes et al. 2001;
83 Chodak et al. 2013). We calculated the 95% upper and lower confidence intervals using
84 10,000 bootstraps. Alpha level was set at $p = 0.05$. Past 3.0 software was used to calculate the
85 various diversity indices.

86 RESULTS

87 During the research work, a total of 202 Antelopes was counted (Table 1) within the
88 sampling duration. The frequency of antelope carcasses differed significantly by market site
89 ($\chi^2 = 36.6$, $df = 2$, $P < 0.0001$), with most animals being traded in Omagwa ($n = 126$ antelope
90 carcasses), followed by Oyigbo ($n = 47$) and Mbiama ($n = 29$). In all markets, the same three
91 species were recorded: *Tragelaphus scriptus* ($n = 24$), *Philantomba walteri* ($n = 141$), and
92 *Neotragus batesi* ($n = 35$) (Figure 1). Sex ratio was even in the three species: *Tragelaphus*
93 *scriptus* (1.6 male : 1 female; $\chi^2 = 0.7$, $df = 1$, $P = 0.402$), *Philantomba walteri* (0.98 male : 1
94 female; $\chi^2 = 0.003$, $df = 1$, $P = 0.953$), and *Neotragus batesi* (0.94 male : 1 female; $\chi^2 = 0.014$,
95 $df = 2$, $P = 0.905$).

96 64.3% of the antelope carcasses were traded during the wet season (inter-seasonal
97 differences: $\chi^2 = 8.5$, $df = 1$, $P < 0.01$). The inter-seasonal differences were not significant in
98 *Tragelaphus scriptus* ($\chi^2 = 0.31$, $df = 1$, $P = 0.578$) and *Neotragus batesi* ($\chi^2 = 3.32$, $df = 1$, P
99 $= 0.068$), whereas they were statistically significant for *Philantomba walteri* ($\chi^2 = 5.6$, $df = 1$,
100 $P < 0.01$).

101 In terms of diversity metrics, Omagwa appeared ecologically better than the other
102 sites, with Mbiama being intermediate and Oyigbo being more depleted: indeed, despite the
103 taxonomical composition of the species was identical across sites, the evenness and diversity
104 indices were highest in Omagwa and lowest in Oyigbo, whereas the opposite was true for the
105 dominance index (Table 2). Interestingly, saturation curves also revealed that, whereas in
106 Omagwa no other antelope species can be expected, the same was not true for the other two
107 sites where the plateau of the curve was not reached (Figure 2).

108 The morphometric characteristics of the different species of antelopes across stations
109 are given in Table S2, showing that, as expected, *Tragelaphus scriptus* carcasses were
110 significantly larger than the other two species in all body measures (in all cases, $P < 0.0001$ at
111 Student t-tests). The market value depended directly on the relative size of the carcasses:
112 thus, *Tragelaphus scriptus* was sold at higher prices than the other two species (Table 3).

113 **DISCUSSION**

114 Recent literature has showed that there is considerable confusion concerning the antelope
115 species in the Niger Delta: for example, for duikers (genera *Cephalophus* and *Philantomba*),
116 only one of the six species cited in the literature were demonstrated as definitely present in
117 the Niger Delta region, and, overall, only six antelope species have been recorded out of
118 which only five were recorded more than once (Petrozzi et al., 2015). Thus, the species
119 diversity of Niger Delta antelopes is by far less than historically reported (e.g., Happold,

120 1987; Powell, 1993; Angelici et al., 1999; Blench, 2007), also because it is likely that some
121 species were wrongly reported for the general area (Petrozzi et al., 2015; Luiselli et al., 2015,
122 2019a). Therefore, the reduced species richness ($n = 3$) observed in the three study stations is
123 not surprising, whereas the total number of carcasses ($n = 202$) was low if we consider (i) the
124 considerable field effort, (ii) the appreciation for antelope meat by local communities
125 (Luiselli et al., 2019b) and (iii) the fact that three distinct localities were monitored.
126 *Philantomba walteri* was the dominant species at all the three study stations as it constitutes
127 about 70% of the total antelope carcasses recorded. This data fully mirrors data presented by
128 Petrozzi et al. (2015). At another site in a forested area of the central Niger Delta,
129 *Philantomba walteri* was also the most abundant species, but also *Tragelaphus scriptus* and
130 *Tragelaphus spekei* (not seen in the present study) had practically the same abundance,
131 whereas *Neotragus batesi* and *Hyaemoschus aquaticus* (also not recorded during the present
132 study) appeared less abundant (Akani et al., 2015). Comparatively, it seems that the antelope
133 species richness is still higher in the forests of the western and central side of the Niger Delta
134 than in the eastern side of the deltaic axis, with only one species (*Philantomba walteri*) being
135 still widespread and abundant. However, the fact that a relatively low number of antelope
136 carcasses has been observed along the study period (much lower than the number of carcasses
137 of small carnivores for instance, see Onuegbu et al., submitted) suggests that the ungulate
138 fauna is already very depleted in the eastern Niger Delta region, as also observed in other
139 African areas with heavy hunting pressure (Fa et al., 1995; Fischer and Linsenmair, 2001;
140 Grande-Vega et al., 2016; Hema et al., 2017).

141 Sex ratio of our observed samples was even for all species. Literature data suggests
142 that sex ratio may vary considerably in *Tragelaphus scriptus* from area to area with some
143 populations having even sex ratios and others having female-skewed ratios (e.g., Waser,
144 1975; Alsopp, 1978; Yazezew et al., 2011) whereas nothing is known on *Philantomba walteri*

145 and *Neotragus batesi*. Thus, although preliminary, our study gives the first-of-ever data on
 146 the adult sex ratio of a reasonable sample for these two ecologically nearly unknown antelope
 147 species.

148 Our data also suggest that antelopes (in particular *Philantomba walteri*) are hunted
 149 more intensely by wet season. These data mirror the same patterns observed with small
 150 carnivores sold in bushmeat markets (Onuegbu et al., submitted), and are in agreement with
 151 information provided by hunters (n = 66) that reported hunting to be more productive at wet
 152 season than at dry season. According to them, the sound from dry grasses/vegetation during
 153 dry season provided an easy escape route for the antelopes thereby reducing their catches
 154 compared to rainy season. According to most of the interviewed hunters, *Philantomba walteri*
 155 and *Neotragus batesi* usually occupy low successional disturbed habitats, unlike *Tragelaphus*
 156 *scriptus* that prefers undisturbed habitats.

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231

232 **Table 1.** Synopsis of the antelope data collected at the three study stations during the research
 233 period.

234

Species	Station 1 (Omagwa)	Station 2 (Oyigbo)	Station 3 (Mbiama)
<i>Tragelaphus scriptus</i>	24	1	1
<i>Philantomba walteri</i>	82	38	21
<i>Neotragus batesi</i>	20	8	7
TOTAL	126	47	29

235

236

237 **Table 2.** Estimates of diversity metrics for antelope assemblages (as indicated by bushmeat
 238 market surveys) in southern Nigeria, after 10,000 bootstraps. Lower = lower 95% confidence
 239 interval; upper = upper 95% confidence interval.

240

	Omagw a	Lowe r	Uppe r	Oyigb o	Lowe r	Uppe r	Mbiam a	Lowe r	Uppe r
Taxa_S	3	3	3	3	3	3	3	3	3
Individuals	126			47			29		
Dominance	0.49	0.42	0.57	0.68	0.54	0.81	0.58	0.45	0.76
Simpson	0.52	0.43	0.58	0.32	0.19	0.46	0.42	0.24	0.55
Shannon	0.89	0.76	0.98	0.56	0.39	0.76	0.69	0.48	0.91
Evenness	0.81	0.71	0.89	0.58	0.49	0.71	0.67	0.54	0.83
Chao-1	3	3	3	3	3	3	3	3	3

241

242

243 **Table 3.** Market value of antelope carcasses by station and by species.

244

245

Species	Station	Price Range (Naira)	Mean Price (Naira)
<i>Philantomba walteri</i>	Omagwa	6000-11000	7500
	Oyigbo	7000-9000	8000
	Mbiana	6800-10000	7850
<i>Neotragus batesi</i>	Omagwa	5000-8000	6500
	Oyigbo	4500-8000	6000
	Mbiana	4500-8000	6000
<i>Tragelaphus scriptus</i>	Omagwa	14000-25000	10500
	Oyigbo	8500-13500	10000
	Mbiana	8000-12000	9500

246

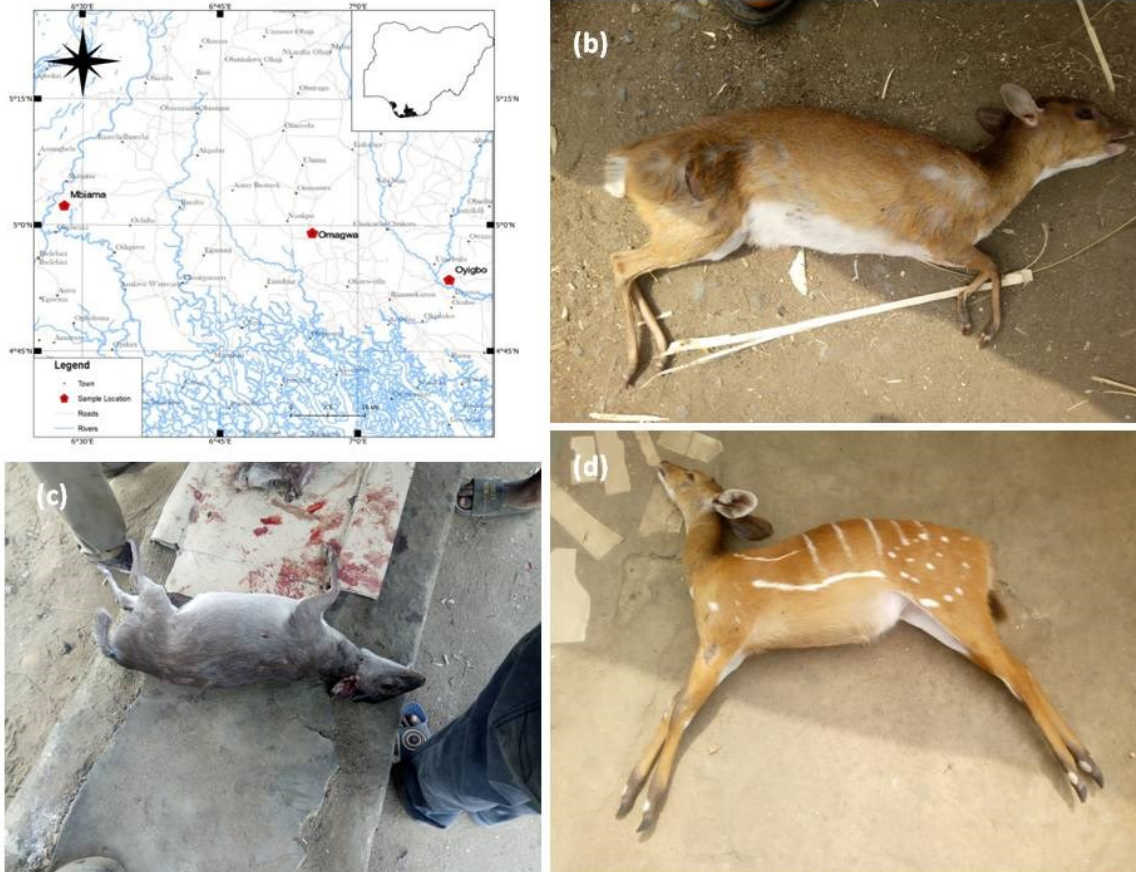
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250 **Figure 1:** Map of Rivers State in southern Nigeria, showing the three sample stations, and the
251 three study species: *Neotragus batesi* (b), *Philantomba walteri* (c) and *Tragelaphus scriptus*
252 (d)

253



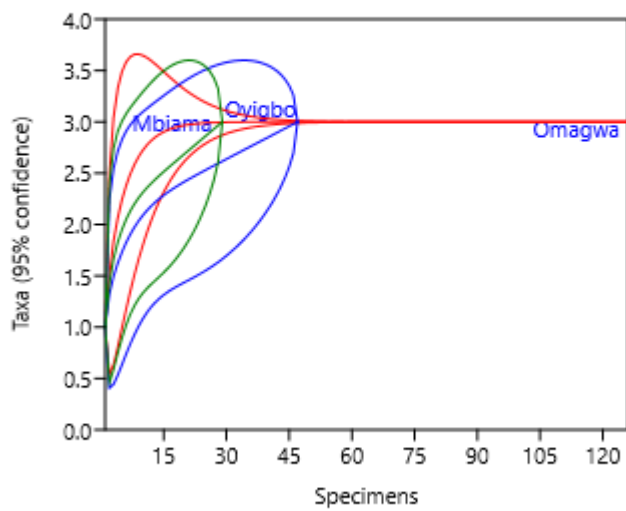
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256 **Figure 2.** (A) Saturation curves (with 95 % confidence intervals after 9999 bootstraps) and
 257 (B) Diversity profiles (95 % confidence, after 9999 bootstraps), for the community diversity
 258 of antelopes at the three study stations

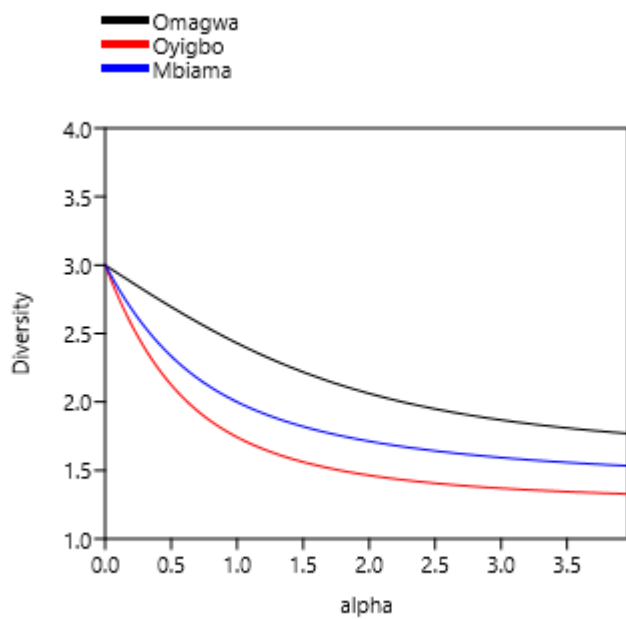
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260 (A)



261

262 (B)



263

264 **ONLINE SUPPLEMENTAL MATERIAL**

265

266 **Table S1:** GIS-based estimates of the dominant tree cover (in terms of % of occupied land)
 267 and of the human population density, for a 7-km-radius buffer along the three surveyed
 268 market sites and another area of the Niger Delta (Swali) used for literature comparison. Data
 269 from Hansen et al. (2013) and Center for International Earth Science Information Network -
 270 CIESIN - Columbia University (2017).

271

Surveyed locality	% of dominant tree cover	human population density (per km ²)
Swali	56	638.2
Mbiama	55	760.1
Oyigbo	16	380.8
Omagwa	29	371.6

272

Table S2. Summary of the morphometric characteristics of the different species of antelopes across stations (mean±SD)

Species	Location	Sex	Weight (kg)	Total Length (cm)	Standard length (cm)	Hind foot (cm)	Forefoot (cm)	Ear (cm)	Body depth (cm)	Tail (cm)	Head (cm)	Neck (cm)
<i>Philantomba walteri</i>	Mbiama	F	6.1±2.31	27.75±2.73	23.06±2.48	11.56±2.6	10.19±2.58	2.89±0.33	10.25±1.16	4.88±1.6	5.31±0.8	3.49±0.25
		M	6.83±2	26.33±6.04	22±5.48	12.61±2.48	11.06±1.99	3.16±0.33	10.94±1.21	5.39±1.87	5.83±1.03	3.63±0.29
	Oyigbo	F	6.77±2.01	28±2.7	23.38±2.38	12.54±3.31	10.29±2.39	3.04±0.36	10.54±1.23	5.46±1.57	5.63±0.91	3.58±0.28
		M	6.48±1.96	26.57±4.7	22.23±4.29	11.97±2.54	10.53±2.18	3.05±0.34	10.6±1.27	5.23±1.73	5.57±0.96	3.59±0.27
	Omagwa	F	6.78±2.05	28.41±2.36	23.64±1.99	11.83±2.55	10.33±2.23	3.06±0.35	10.55±1.09	5.47±1.49	5.68±0.86	3.61±0.28
		M	6.19±1.78	24.94±5.29	20.75±4.83	11.71±2.17	10.52±2	3.05±0.34	10.52±1.13	4.91±1.72	5.42±0.78	3.66±0.37
<i>Neotragus batesi</i>	Mbiama	F	5.03±0.45	16.83±2.02	13.67±2.08	11.83±2.02	10.83±2.02	4.03±0.45	10.67±1.26	3.33±0.58	4.83±0.21	3.9±0.1
		M	5.14±0.31	17.17±1.61	14±1.73	12.17±1.61	11.17±1.61	4.1±0.36	10.83±1.04	3.33±0.58	4.9±0.1	3.9±0.1
	Oyigbo	F	5.01±0.46	16.67±2.08	13.67±2.08	11.67±2.08	10.67±2.08	3.97±0.47	10.5±1.32	3.33±0.58	4.77±0.15	3.83±0.06
		M	5.21±0.41	17.5±2.12	14.5±2.12	12.5±2.12	11.5±2.12	4.15±0.49	11±1.41	3.5±0.71	4.85±0.07	3.85±0.07
	Omagwa	F	4.89±0.15	16.07±0.53	12.86±0.38	11.07±0.53	10.07±0.53	3.84±0.16	10.14±0.38	3.07±0.19	4.86±0.15	3.99±0.25
		M	5.35±0.68	17.64±2.32	14.71±2.63	12.64±2.32	11.64±2.32	4.26±0.61	11±1.29	3.57±0.73	4.89±0.17	4±0.26
<i>Tragelaphus scriptus</i>	Mbiama	F	40±0	36±0	30±0	18±0	15±0	3±0	16.5±0	7±0	6.5±0	6.5±0
	Oyigbo	M	58±0	47±0	39±0	22±0	19.5±0	4.5±0	18±0	9±0	8±0	7±0
	Omagwa	F	46.5±3.11	44.775±2.05	35.625±1.49	19.375±1.11	17.75±1.19	3.833333±0.29	18.125±1.65	8±1.22	7.125±0.75	6.75±0.5
		M	52.91±5.22	47.07±3.42	37.5±3.16	20.94±1.86	18.72±1.66	4.81±1.03	15.44±1.67	9.17±0.56	7.94±0.88	7.39±0.74

