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

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Running Head: Niger Delta antelopes

INTRODUCTION

Nigeria, currently the largest, richest and most densely populated country in Africa, by the early 1990s was already as densely populated as Western Europe with an average of 130 people per km^2 (Janus and Jaeger, 2011). Since several decades, the rapidly growing population was placing enormous pressures on the country's natural resource base, and most of the formerly extensive natural forest and savanna habitats have been degraded or destroyed by the expansion of agriculture, excessive wood-cutting to supply timber and fuelwood, and overgrazing of grasslands by livestock (e.g., Osuide, 1990). In addition to widespread degradation and destruction of natural habitats, wildlife has suffered severely from uncontrolled hunting for bushmeat (e.g., Martin, 1983; Anadu et al., 1988; Fa et al., 2006). In southern Nigeria, antelopes have always been purposely targeted among the best target of hunting for bushmeat because of they are highly valued as tasteful food by local communities (Luiselli et al., 2019). Thus, their wild populations may have been possibly depleted (e.g., Blench, 2007; Luiselli et al., 2015; Petrozzi et al., 2015), despite no quantitative study has ever been performed in order to evaluate the demographic characteristics and the structure of Nigerian antelope communities.

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

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/km^2 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: $D = 1-$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 were 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 caracasses 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)
Tragelaphus scriptus	24	1	1
Philantomba walteri	82	38	21
Neotragus batesi	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

	Omagwa	Lower	Upper	Oyigbo	Lower	Upper	Mbiama	Lower	Upper
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

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242

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

244

245

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

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249

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*
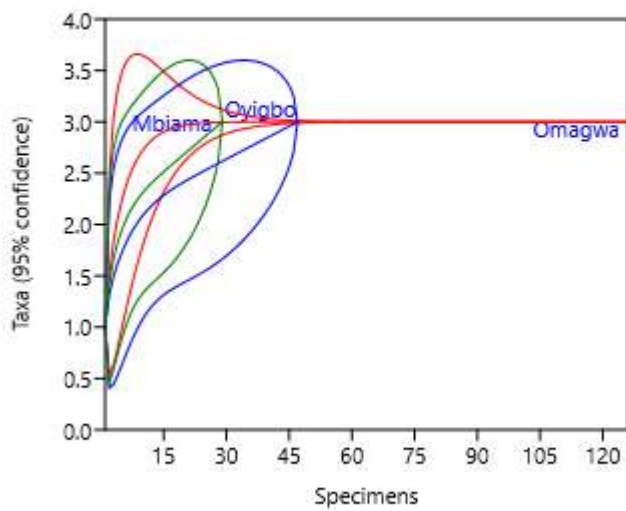
252 (d)

253
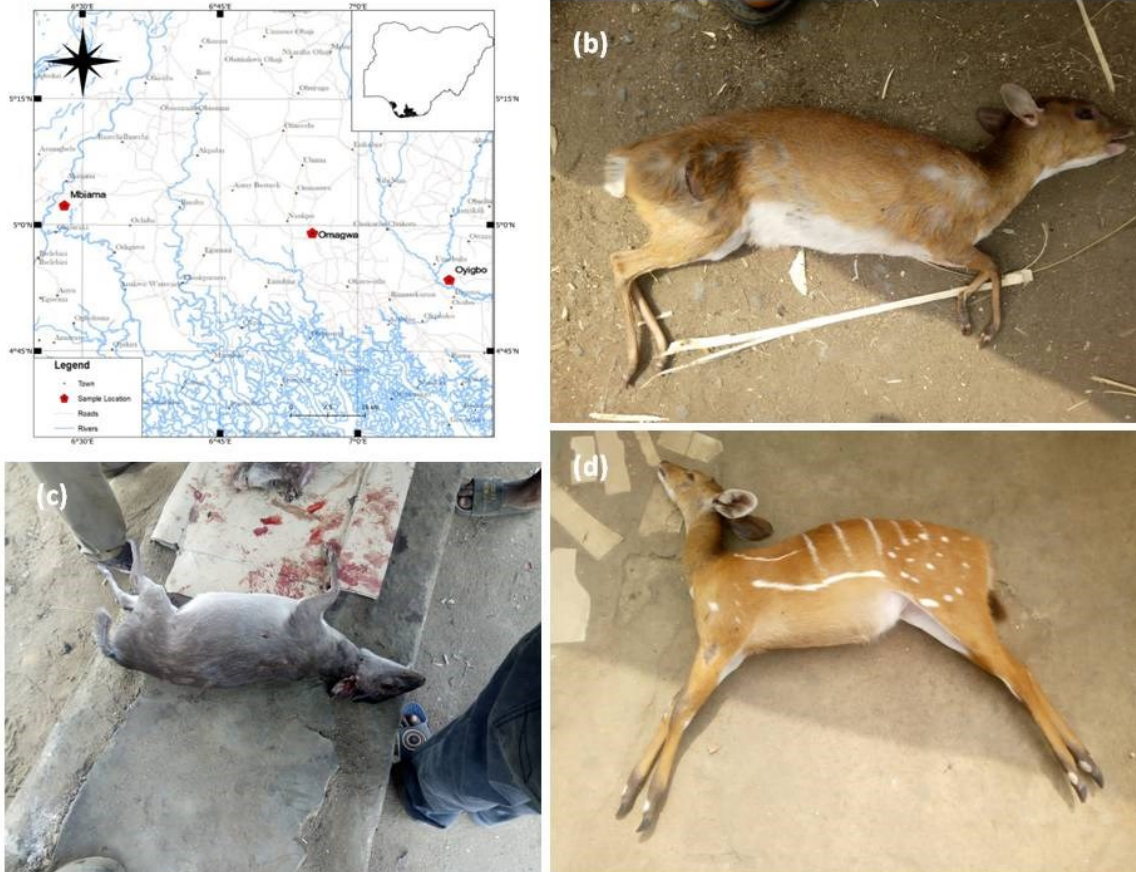
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255

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

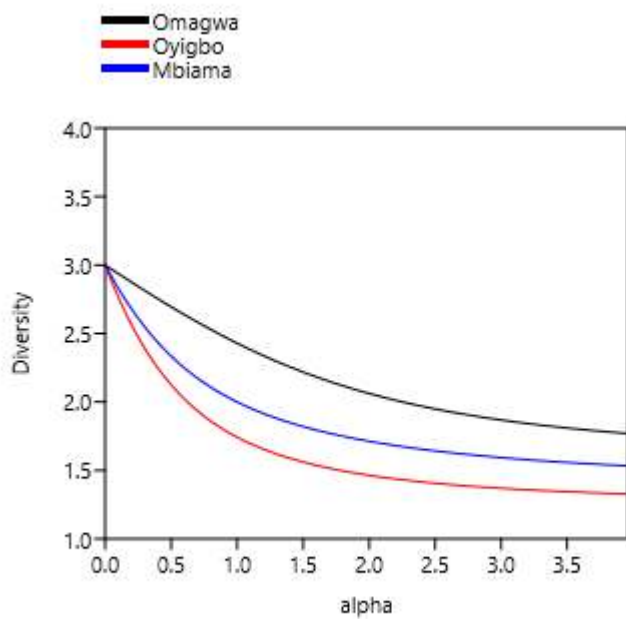258   of antelopes at the three study stations

259

260   **(A)**

261

262   **(B)**

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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)
Philantomba walteri	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
Neotragus batesi	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
Tragelaphus scriptus	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