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

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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

The present study was carried out by monitoring three bushmeat markets: Omagwa (04°59'04"N, 06°55'05"E), Oyigbo (04°53'32"N, 07°10'0"E) and Mbiama (05°03´0"N, 06°27'0"E) in the Rivers State, southern Nigeria (Fig. 1). Rivers State, with over 5 million inhabitants and more than 630 persons/km^2 density (Rivers State Government, 2019), has undergone, during the last 30 years, a strong agricultural and industrial expansion that caused severe fragmentation of the existing forests (Niger Delta Environmental Survey, 1998; Akani, 2008). The study area's climate is characterized by a long rainy season from April through to the end of September.

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

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

We used contingency table χ^2 tests to investigate differences among the observed number of individual animals by sex, season, and market. Saturation curves were built for each market site with 95 % confidence intervals. Bootstrap analysis was applied to generate upper and lower confidence intervals of all indices, with 9,999 random samples, each with the same total number of individuals as in each original sample being generated (Harper 1999). Inter-specific differences in the means of a set of morphometric characteristics (Table S2) were assessed by Student t-test.

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

RESULTS

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

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

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

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

DISCUSSION

Recent literature has showed that there is considerable confusion concerning the antelope species in the Niger Delta: for example, for duikers (genera *Cephalophus* and *Philantomba*), only one of the six species cited in the literature were demonstrated as definitely present in the Niger Delta region, and, overall, only six antelope species have been recorded out of which only five were recorded more than once (Petrozzi et al., 2015). Thus, the species diversity of Niger Delta antelopes is by far less than historically reported (e.g., Happold, 1987; Powell, 1993; Angelici et al., 1999; Blench, 2007), also because it is likely that some species were wrongly reported for the general area (Petrozzi et al., 2015; Luiselli et al., 2015, 2019a). Therefore, the reduced species richness (n = 3) observed in the three study stations is not surprising, whereas the total number of carcasses (n = 202) was low if we consider (i) the considerable field effort, (ii) the appreciation for antelope meat by local communities (Luiselli et al., 2019b) and (iii) the fact that three distinct localities were monitored. *Philantomba walteri* was the dominant species at all the three study stations as it constitutes about 70% of the total antelope caracasses recorded. This data fully mirrors data presented by Petrozzi et al. (2015). At another site in a forested area of the central Niger Delta, *Philantomba walteri* was also the most abundant species, but also *Tragelaphus scriptus* and *Tragelaphus spekei* (not seen in the present study) had practically the same abundance, whereas *Neotragus batesi* and *Hyaemoschus aquaticus* (also not recorded during the present study) appeared less abundant (Akani et al., 2015). Comparatively, it seems that the antelope species richness is still higher in the forests of the western and central side of the Niger Delta than in the eastern side of the deltaic axis, with only one species (*Philantomba walteri*) being still widespread and abundant. However, the fact that a relatively low number of antelope carcasses has been observed along the study period (much lower than the number of carcasses of small carnivores for instance, see Onuegbu et al., submitted) suggests that the ungulate fauna is already very depleted in the eastern Niger Delta region, as also observed in other African areas with heavy hunting pressure (Fa et al., 1995; Fischer and Linsenmair, 2001; Grande-Vega et al., 2016; Hema et al., 2017).

Sex ratio of our observed samples was even for all species. Literature data suggests that sex ratio may vary considerably in *Tragelaphus scriptus* from area to area with some populations having even sex ratios and others having female-skewed ratios (e.g., Waser, 1975; Alsopp, 1978; Yazezew et al., 2011) whereas nothing is known on *Philantomba walteri* and *Neotragus batesi*. Thus, although preliminary, our study gives the first-of-ever data on the adult sex ratio of a reasonable sample for these two ecologically nearly unknown antelope species.

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

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

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

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

	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

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

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

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

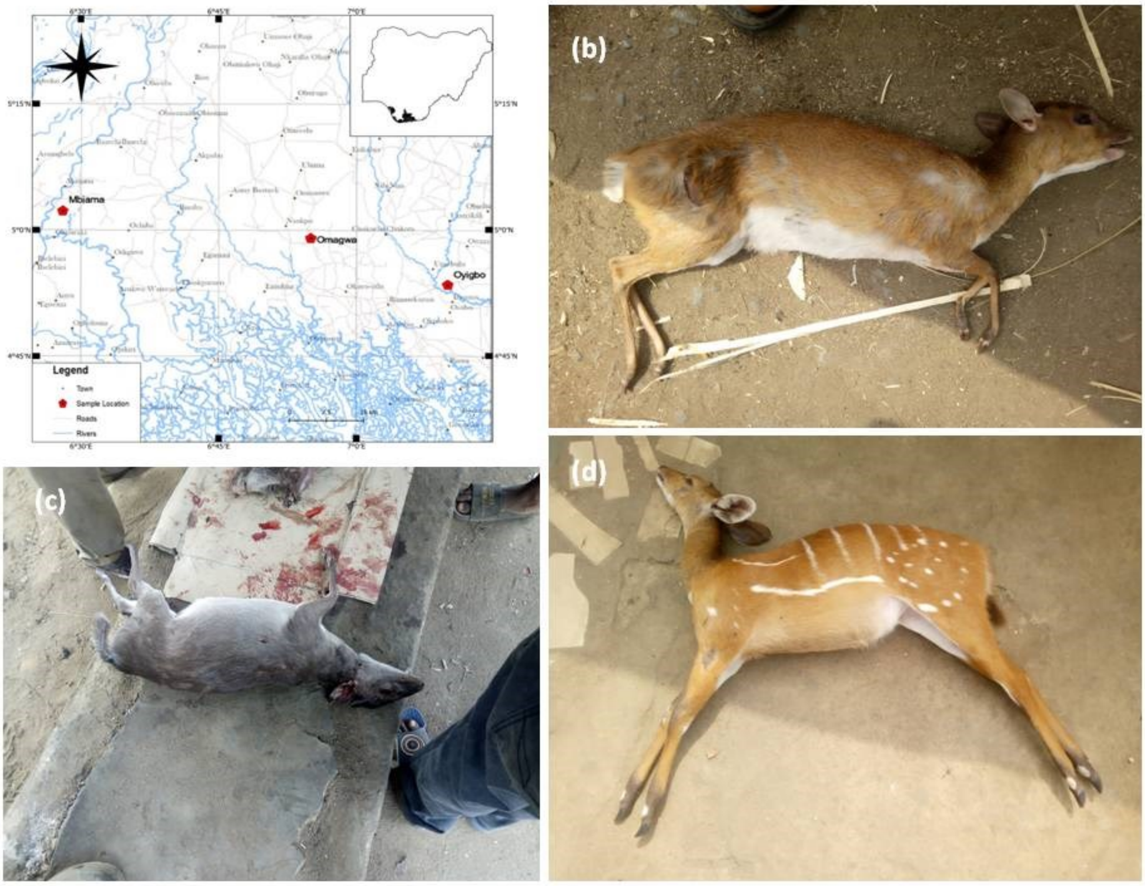
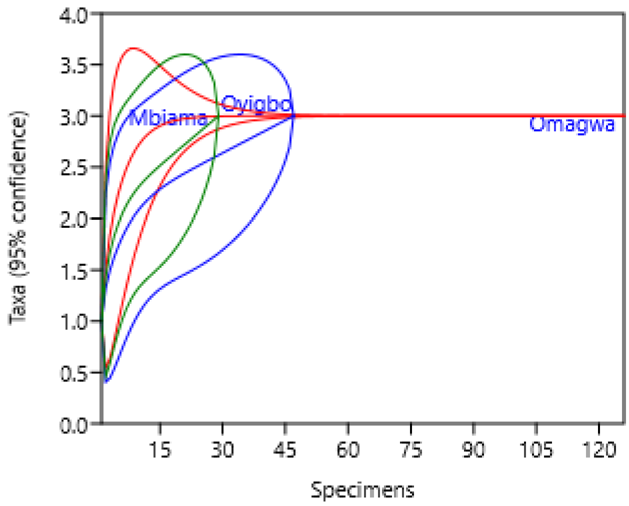
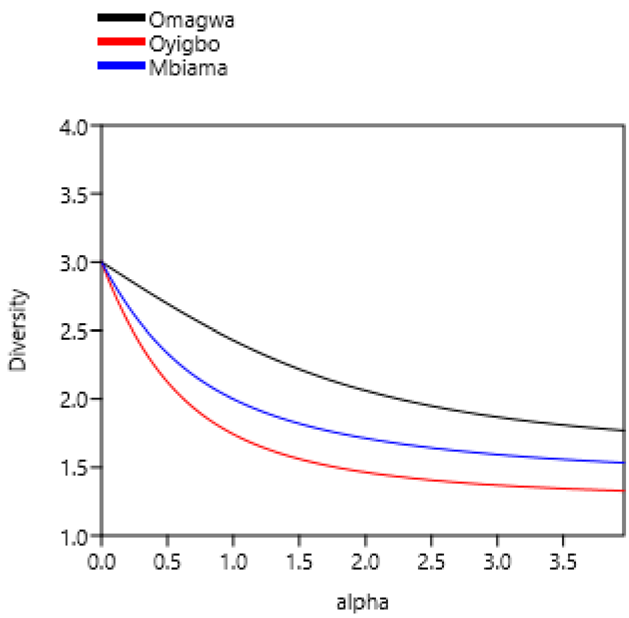


Figure 2. (A) Saturation curves (with 95 % confidence intervals after 9999 bootstraps) and (B) Diversity profiles (95 % confidence, after 9999 bootstraps), for the community diversity of antelopes at the three study stations

(A)



(B)



ONLINE SUPPLEMENTAL MATERIAL

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

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

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