Short Communication

Biotic homogenization in the Niger Delta (Nigeria): evidence from small carnivores in bushmeat markets

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Running Head: Niger Delta small carnivores

1 INTRODUCTION

Carnivores are indicative of ecosystem health and integrity, and can potentially affect food-web and community structure of lower trophic levels. Several studies of sympatric African carnivore species have demonstrated that ecological separation is primarily related to dietary differences (Ray & Sunquist, 2010). As specialization and resource selectivity is generally stronger in small carnivores than large ones they may serve as useful indicator species of the state of an ecosystem. Thus, understanding the changes taking place in the assemblage and abundance of carnivores may allow the determination of the state of conservation of a particular habitat.

In the Niger Delta, members of four small carnivore families [Mustelidae (n = 2 species), Viverridae (n = 2 species), Nandiniidae (n = 1 species) and Herpestidae (n = 3 species)] are found in forest and forest-derived habitats in the region (Luiselli et al., 2016). However, knowledge of their biology is still poorly understood primarily because of their secretive and nocturnal habits (e.g., Charles-Dominique, 1978; Ray & Sunquist, 2001; Emmons et al., 2009; Gaubert, 2013).

Small carnivores are regularly consumed as bushmeat and sold in markets in west and central Africa (Fa & Brown, 2009; Petrozzi et al., 2016). Using records of species and individuals of small carnivores sold in bushmeat markets it is possible not just to uncover noteworthy aspects of their biology, but also determine whether hunting may be causing biotic homogenization within the catchment supplying the markets. In this paper, we use data from three markets in the surroundings of the city of Port Harcourt in Rivers State (Niger Delta, Nigeria) to evaluate whether a biotic homogenization process on taxonomic, species richness diversity characteristics (Olden & Rooney, 2006), and perhaps substitution of species, have occurred. We also compare

45 our results with data from other markets in the same area, and from other sites in southern
46 Nigeria and neighbouring Benin Republic.

47 2 MATERIALS AND METHODS

48 This study was carried out in the Rivers State, Nigeria (Fig. S1). Rivers State has over 5 million
49 inhabitants and a density of more than 630 persons/km^2 (Rivers State Government, 2019).
50 During the last 30 years, agricultural and industrial expansion throughout the region has caused
51 severe fragmentation of the existing forests (Niger Delta Environmental Survey, 1998; Akani,
52 2008). The study area's climate is characterized by a long rainy season from April through to the
53 end of September (Fig. S2).
54
55 We monitored three bushmeat markets: Omagwa, Oyigbo and Mbiama (Table S1). These study
56 stations were chosen because they represent localities in which hunting, alongside traditional
57 agriculture, provide important economic revenues for the resident rural population. These
58 localities differ in terms of vegetation cover and human population density (Hansen et al., 2013;
59 Center for International Earth Science Information Network - CIESIN - Columbia University,
60 2017); the latter being significantly higher in Mbiama than in the other localities (Table S2).
61 Hunters living in bushland and forest patches, often >7 km away from the market, regularly
62 supply a variety of animal carcasses for their sale.
63
64 In this study, we made the implicit assumption that small carnivore abundance in bushmeat
65 markets can be used as a proxy of small carnivore abundance in the field. We surveyed bushmeat
66 markets during the dry season (December 2017- March 2018) and in the wet season (May 2018-
67 August 2018). Sampling effort was identical in the three market sites; we visited each market

three times per week during eight months (48 daily visits in each season). During each sampling day, we counted all animal carcasses on sale, including small carnivores. All markets were visited between 7.00-11.00am, in order to be able to count and inspect carcasses as hunters dropped them with the bushmeat traders, and before traders dressed these (burning off the hairs/fur and butchering) making it more difficult to identify the species.

We used contingency table χ^2 tests to investigate differences among the observed number of individual animals by sex and market, and Pearson's coefficient for the correlation between monthly rainfall patterns and number of carcasses in the various markets. We also calculated diversity indices to compare community structure data collected in this study with those from markets from the same study area in 2009 (Okiwelu et al., 2009), with the Swali market in the central Niger Delta forests (Akani et al., 2015) and in the bushland-plantation mosaic in southern Benin (Djagoun & Gaubert, 2009). 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.

3 RESULTS

A total of 1,206 carcasses of small carnivores were recorded in the three study markets. The largest number (n = 699) was observed at the Omagwa market, followed by Oyigbo (n = 416)

and Mbiama (n = 91); differences among markets were significant (χ^2 = 276.6, df = 2, P< 0.0001).

We recorded four different taxa, all Least Concern in the IUCN's Red List (LC, IUCN, 2019): Flat-headed kusimanse *Crossarchus platycephalus* (n = 1,176), African civet *Civettictis civetta* (n = 21), African palm civet *Nandinia binotata* (n = 6), and genets *Genetta* spp., possibly *G. maculata* (n = 3) (Figure 1). In all three markets, *C. platycephalus* accounted for over 97% of the total number of observed individuals, and the relative frequency of occurrence of the various species did not vary significantly among study areas ($P > 0.05$ at χ^2 test with df = 2).

The number of carcasses was higher in the wet season than in the dry season, independently of the market and species (Table S3). The increase in the number of traded carcasses from the dry months to the wet months was smooth and regular in the Oyigbo market, whereas numbers varied significantly in the other two markets (Figure 2). The number of carcasses was significantly positively correlated with monthly rainfall in all study markets (in all cases, P < 0.05).

Sex ratios were significantly skewed towards females (Table S4) in both *C. platycephalus* (observed-versus-expected χ^2 = 169.4, df = 1, P < 0.0001) and *C. civetta* (χ^2 = 4.4, df = 1, P < 0.05), but sample sizes in *N. binotata* and *Genetta* spp. For *C. platycephalus,* the same female-biased sex ratio was observed during both the dry (χ^2 = 21.3, df = 1, $P < 0.0001$) and the wet season (χ^2 = 17.5, df = 1, $P < 0.0001$).

Diversity measures differed significantly among markets, with a much higher dominance in our study area (three markets pooled in the analyses) compared to all other sites, and with a higher diversity and evenness for the central Niger Delta (Bayelsa) and in southern Benin (Table 1). Interestingly, the Bayelsa and the Benin sites were nearly identical in terms of diversity metrics, whereas the small carnivore assemblage in Rivers State had a much higher dominance index value and a lower Shannon diversity index compared to 2009 (Table 1). Diversity profiles indicated that the three Rivers State markets were remarkably different from the other areas, with the Bayelsa State and southern Benin being very similar (Figure 3). Frequency differences of the various species in the three Rivers State markets compared to data in Okiwelu et al. (2009) (n = 1 market) were highly significant (χ^2 test with df = 3, $P < 0.0001$), with the dominant species in our three markets (*C. platycephalus*) not recorded ten years previously.

4 DISCUSSION

The basic premise of our study is that because hunters do not specifically target small carnivores, the numbers appearing in the markets reflect their relative abundance in the market catchment areas. Using these data, we indicate that there is evidence that biotic homogenization and species substitution is occurring in the eastern Niger Delta region (e.g., Petrozzi et al., 2015; Luiselli et al., 2015).

Ongoing homogenization process has already been shown for snakes and chelonians (Luiselli, 2001, 2002). Similarly, we demonstrate in our study that there is evidence of impoverishment of the small carnivore community in the Rivers State agro-forestry systems from comparisons between our study area and more heavily forested areas in the central Niger Delta (Akani et al.,

2015a) and in Benin (Djagoun & Gaubert, 2009) (Table S3). We show that in our study area only four species were found compared to 5-7 taxa in the central Niger Delta and Benin. Moreover, the dominance index for the three surveyed markets (which were almost identical in the three sites) was significantly higher, whereas the Shannon diversity and evenness indices were significantly higher in the central Niger Delta and Benin sites. Notably, in the three studied markets, the smallest species (i.e. *C. platycephalus*), accounted for more than 95% of all individuals observed. This species is also the best adapted to forest-derived grasslands as it feeds essentially on rodents, which become an abundant food resource in such altered habitats. Thus, our data suggests a process of functional similarity of biotas over time, associated with the establishment of species that have similar 'roles' in the ecosystem and with the loss of those possessing unique functional 'roles' (Olden & Rooney, 2006).

Comparison of our results with data obtained for the same area about a decade ago (Okiwelu et al., 2009), show that although only three species were recorded then, their relative abundances were more equilibrated than in the present study. There were also significant differences in the frequency of occurrence of the various species, particularly the dramatic increase in the relative abundance of *C. platycephalus*; in 2009 the species was not observed. This is a clear signal of an ongoing species substitution process, which mirrors data on cobras from the same area, where *Naja nigricollis* (a mainly savannah species) was clearly substituting *N. melanoleuca* (a mainly forest species) in almost every suitable habitat in the region (Luiselli, 2002). Analogous to the patterns observed for cobras, *C. platycephalus*, a small group-living species typical in deforested and heavily altered landscapes, is taking over (Petrozzi et al., 2014). This species is nowadays

very common in the deforested grasslands and plantations of the Port Harcourt region, possibly due to the greater abundance of rodents (their main food type) in these habitats.

Our study also confirmed the occurrence of *N. binotata* in the surroundings of Port Harcourt, also shown by Luiselli et al. (2015) and Petrozzi et al. (2015), though this species was not considered present in the Niger Delta by Blench (2007). This species is also one of the most intensively traded carnivore species in African forests (Bahaa-el-din et al., 2013; Doughty et al., 2015).

In our study we show there is clear seasonal pattern in the number of carcasses of *C. platycephalus,* that peaked during the rainy months (see also Akani et al., 2015a, 2015b; Amadi et al., 2015). Although for the other three species our sample was too small for any statistical analysis, in the Niger Delta *N. binotata* was previously recorded slightly more often during the wet season with no significant inter-seasonal difference (Petrozzi et al., 2015). In Gabon, *N. binotata* females gave birth to young from June to January each year (that is in both dry and wet seasons), which is apparently linked to fruiting seasonality as this species is mainly frugivorous (Charles-Dominique, 1978).

Finally, in two of the species recorded (*C. platycephalus* and *C. civetta*) the sex-ratio of the traded individuals was significantly female-skewed. Data on sex-ratios of African small carnivores are very scanty, thus comparisons are problematic. Female-skewed sex-ratio was also observed in *N. binotata* in Gabon (Charles-Dominique, 1978), but sex ratio was even in Nigerian *N. binotata* and *C. civetta* (Okiwelu et al., 2009), or males were significantly more numerous than females in other small carnivore species of bushmeat markets in Nigeria, including *Genetta* sp. (Okiwelu et al., 2010).

DATA STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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277 **Table 1**. Estimates of diversity metrics for small carnivore assemblages (as indicated by bushmeat market surveys) in southern

278 Nigeria and southern Benin, after 10,000 bootstraps. Lower = lower 95% confidence interval; upper = upper 95% confidence interval.

	Rivers (this study)	Lower	Upper	Rivers (Okiwelu et al., 2009)	Lower	Upper	Bayelsa (Akani et al., 2015)	Lower	Upper	Benin (Djagoun & Gaubert, 2009)	Lower	Upper
Taxa_S	4	4	4	3	3	3	5	5	5	7	7	7
Individuals	1206	1206	1206	1126	1126	1126	157	157	157	72	72	72
Dominance_D	0.9512	0.9336	0.9673	0.4937	0.470 7	0.519 3	0.2473	0.222 8	0.291 7	0.25	0.212 2	0.311 7
Simpson_1-D	0.0488	0.0327 4	0.0663 3	0.5063	0.480 6	0.529 2	0.7527	0.708 3	0.777 2	0.75	0.687 9	0.787 4
Shannon_H	0.1364	0.0975 5	0.1771	0.8543	0.816	0.888 3	1.501	1.405	1.553	1.569	1.391	1.698
Evenness_e^H/S	0.2865	0.2756	0.2984	0.7833	0.753 8	0.810 4	0.8969	0.815 1	0.945 4	0.6859	0.574 2	0,780 3
Chao-1	4	4	4	3	3	3	5	5	5	7	7	8

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Captions for the figures

Figure 1: The four observed small carnivores: (a) *Civettictis civetta* (from Omagwa), (b) *Genetta* sp. (from Oyigbo), *Crossarchus platycephalus* (from Omagwa), and (d) *Nandinia binotata* (from Omagwa)

Figure 2: Month-by-month variation in the number of carcasses carried to the three market sites, and total sample (= data from the three markets pooled), for the four species of small carnivores at the study area

Figure 3. Diversity profiles for the small carnivore community diversity at the four areas in Nigeria and Benin, with 95% confidence intervals calculated after 10,000 bootstraps.

ONLINE SUPPLEMENTAL MATERIAL

Table S1: Sampled study stations and their coordinates, including the Local Government Area (LGA) and the access road

Station	Latitude	Longitude	LGA	Access road
Omagwa	04°59'04"N	06°55'05"E	Ikwerre	Port Harcourt- Owerri road
Oyigbo	04°53'32"N	07°10'0"E	Oyigbo	Port Harcourt-Aba road
Mbiama	05°03´0"N	06°27'0"E	Ahoada	East –West road

Table S2: 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 S3: Seasonal variation on the abundance of small carnivores recorded from the three sampled bushmeat markets in Rivers State.

	Omagwa		Oyigbo		Mbiama		TOTAL
	Dry	Wet	Dry	Wet	Dry	Wet	
Civettictis civetta	4	11	1	4	0	1	21
Genetta sp.	0	2	0	1	0	0	3
Crossarchus platycephalus	291	389	181	225	36	54	1176
Nandinia binotata	0	2	1	3	0	0	6
TOTAL	295	404	183	233	36	55	1206

316 **Table S4:** Sex ratio of the four study species by season, on the basis of the observed carcasses at
317 the three study stations in southern Nigeria

	Dry season		Wet season		TOTAL	
	males	females	males	females	males	females
Civettictis civetta	1	4	3	13	4	17
Genetta sp.	0	0	1	2	1	2
Crossarchus platycephalus	202	306	258	410	460	716
Nandinia binotata	1	0	2	1	3	1
TOTAL	204	310	264	426	468	736

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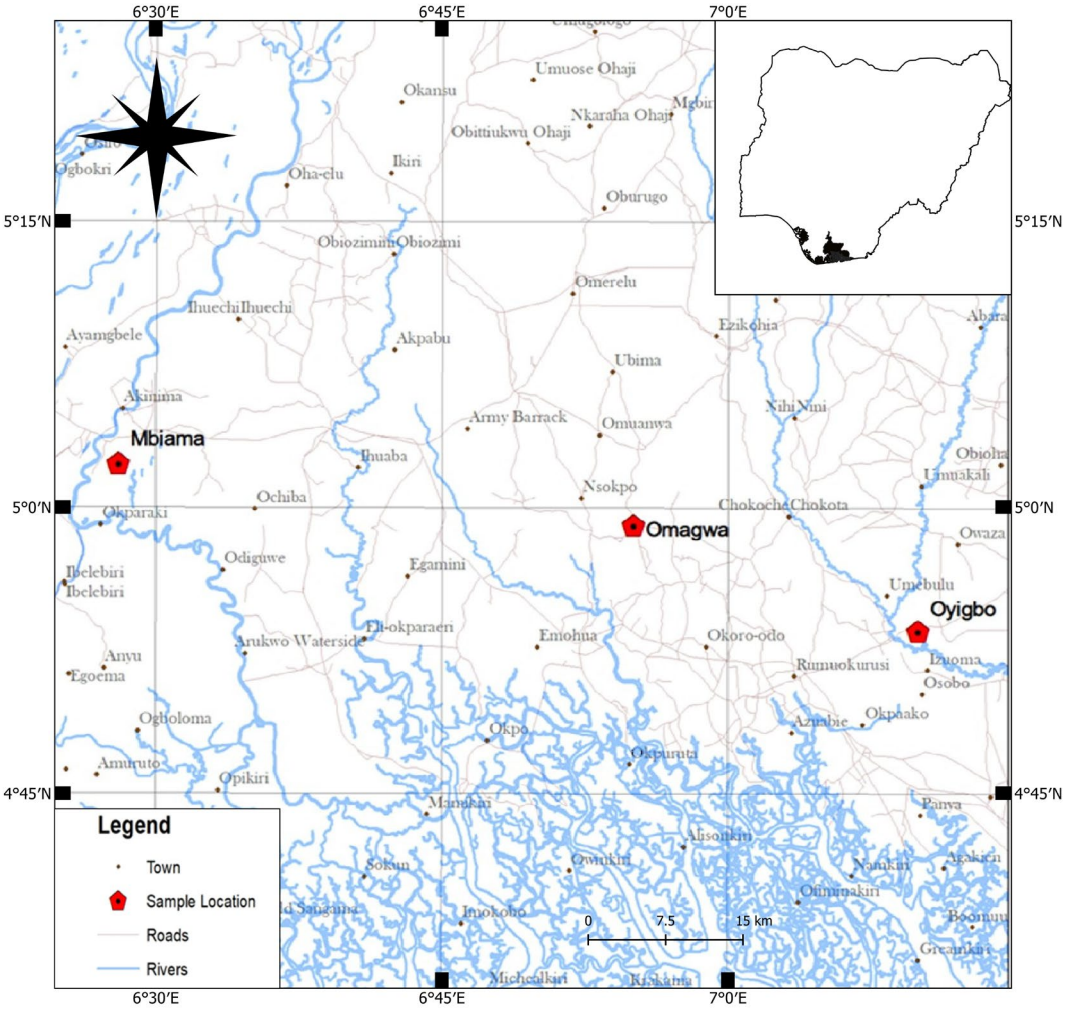
320 **Figure S1:** Map of Rivers State in southern Nigeria, showing the three sample stations



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323 **Figure S2**. Rainfall (mm) patterns of the study area throughout the year.
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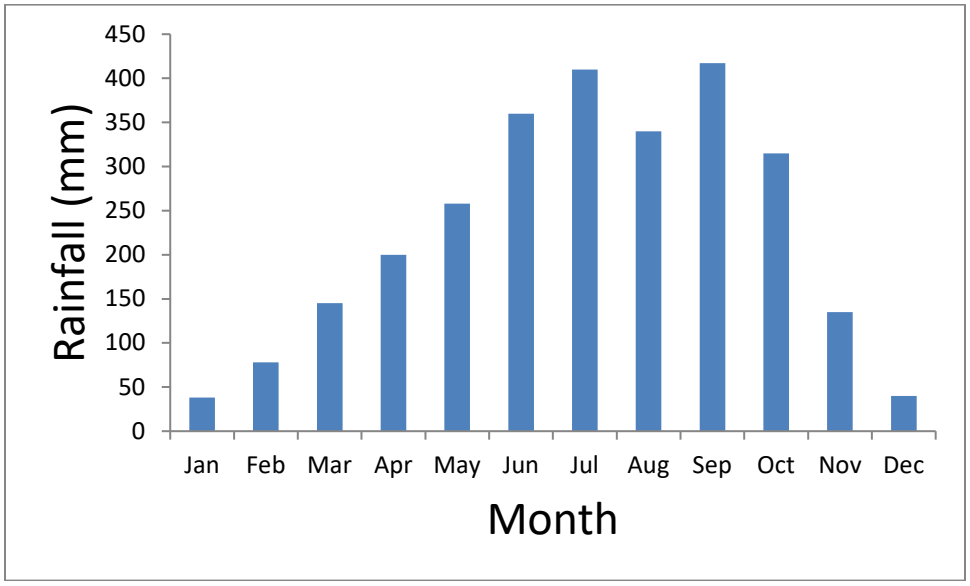

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