

PUBLICATION INFORMATION

This is the author's version of a work that was accepted for publication in the Journal of Zoology. Changes resulting from the publishing process, such as peer review, editing, corrections, structural formatting, and other quality control mechanisms may not be reflected in this document. Changes may have been made to this work since it was submitted for publication. A definitive version was subsequently published in <https://doi.org/10.1111/jzo.12925>

Digital reproduction on this site is provided to CIFOR staff and other researchers who visit this site for research consultation and scholarly purposes. Further distribution and/or any further use of the works from this site is strictly forbidden without the permission of the Journal of Zoology.

You may download, copy and distribute this manuscript for non-commercial purposes. Your license is limited by the following restrictions:

1. The integrity of the work and identification of the author, copyright owner and publisher must be preserved in any copy.
2. You must attribute this manuscript in the following format:

This is a accepted version of an article by Petrozzi, F., Akani, G.C., Eniang, E.A., Ajong, S.N., Funk, S.M., Fa, J.E., Amadi, N., Dendi, D. and Luiselli, L., 2021. **Generalist, selective or 'mixed' foragers? Feeding strategies of two tropical toads across suburban habitats.** Journal of Zoology. <https://doi.org/10.1111/jzo.12925>



1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32

Generalist, selective or “mixed” foragers? Feeding strategy of two tropical toads across suburban habitats

F. Petrozzi¹, G. C. Akani^{2,3}, E. A. Eniang⁴, S. N. Ajong^{3,5}, S. M. Funk⁶, J. E. Fa^{7,8}, N. Amadi², D. Dendi^{2,3,9}, L. Luiselli^{2,3,9}

¹Ecolobby, Rome, Italy fapetrozzi@gmail.com

²Department of Animal and Environmental Biology, Rivers State University of Science and Technology, PMB 5080, Port Harcourt, Rivers State, Nigeria gakanina2000@yahoo.com; lucamaria.luiselli@uniroma3.it; king.amadi@ust.edu.ng

³Institute for Development, Ecology, Conservation & Cooperation, via G. Tomasi di Lampedusa 33, I-00144 Rome, Italy d.dendi@ideccngo.org l.luiselli@ideccngo.org

⁴Department of Forestry and Wildlife, University of Uyo, Nigeria edemeniang@yahoo.com

⁵Department of Fisheries, Lagos State University, Ojo, Lagos, Nigeria ajong.stephanie@gmail.com

⁶NatureHeritage, Jersey, Channel Islands smf@natureheritage.org

⁷Department of Natural Sciences, School of Science and the Environment, Manchester Metropolitan University, Manchester, M1 5GD, UK jfa949@gmail.com

⁸Center for International Forestry Research (CIFOR), CIFOR Headquarters, Bogor, 16115, Indonesia

⁹Department of Zoology and Animal Biology, University of Lomé, Lomé, Togo

Running title

Diet of suburban African toads

Keywords

Diet, West Africa, *Sclerophrys* toads, urbanisation, urban habitats, tropics

Correspondence

Department of Animal and Environmental Biology, Rivers State University of Science and Technology, PMB 5080, Port Harcourt, Rivers State, Nigeria

Email: lucamaria.luiselli@uniroma3.it

33 **Abstract**

34

35 Suitable habitats for anurans can be found in the ever-growing tropical urban environments but anurans'
36 adaptations to urban conditions, including their trophic ecology remain largely unknown. We studied the
37 food habits of two generalist, widespread West African *Sclerophrys* adult toads: African common (*S.*
38 *regularis*) and Hallowell's toad (*S. maculata*). The first was studied in Lomé (Togo), Cotonou (Benin) and
39 Ikeja (Nigeria), and the second in Port Harcourt and Ikeja (both Nigeria); the latter city represents the only
40 studied sympatric occurrence. Mean dietary overlap between population pairs was relatively high, and diet
41 composition of the two species when sympatric did not differ significantly. Food niche width was
42 significantly positively correlated with local rainfall in both species, and diet composition changed
43 significantly between the dry and wet seasons. Diversity metrics revealed that females had a more diversified
44 diet, with higher evenness and lower dominance index values than males. The diet of both species was not
45 correlated to prey type availability, in both the wet and dry season. Both toad species targeted specific food
46 items rather than opportunistically consume prey as observed in most anurans which may be a response to
47 high anuran diversity typically found in the tropics or an adjustment to urban habitats.

48

49 **Introduction**

50

51 Research on the trophic ecology of adult anuran amphibians has greatly contributed to our understanding of
52 the role these organisms play in ecological communities (e.g., Toft 1985, Vignoli & Luiselli 2012).
53 Investigations on the role of anurans in tropical and subtropical natural amphibian communities have been
54 undertaken in South America (Toft 1980, 1981, Parmelee 1999, Piatti & Souza 2011, Talione Sabagh et al.
55 2012, Moreno-Barbosa & Hoyos-Hoyos 2014, Huckembeck et al. 2018, e.g., Brandão et al. 2020) and West
56 Africa (Barbault 1974, Eniang et al. 2003, Hirschfeld & Rödel 2011, Onadeko 2011, Akani et al. 2011,
57 Enabulele & Aisien 2012, Tohé et al. 2015, Ofori et al. 2021). Whilst studies on urban anurans have typically
58 addressed species richness, population density and habitat availability (e.g., Rubbo & Kiesecker 2005,
59 Smallbone et al. 2011, Westgate et al. 2015, Konowalik et al. 2020), the impact of urban habitat modification
60 on anurans' feeding ecology has been less studied (Kovács et al. 1995, López et al. 2015). In particular,
61 studies of the trophic ecology of amphibians in the tropics are rare (Santana et al. 2019, Ofori et al. 2021).
62 Urbanisation leads to changes in micro-climate, water balance, water quality, hydrology of wetlands and
63 adjacent habitats, and to pollution increase and stress. Urban habitats are often characterized by a reduced
64 amphibian diversity compared to the pre-urbanized habitat (Rubbo & Kiesecker 2005). Amphibian species
65 composition is often altered in urban habitats and new communities can emerge as the result of the inclusion
66 of invasive species. Iglesias-Carrasco et al. (2017) have summarized the most severe effects of urbanisation
67 on amphibians as: 1) sensitivity to toxic substances because of their highly permeable skin, 2) artificial
68 limitations of dispersal opportunities, 3) reduced breeding opportunities due to the disappearance of

69 wetlands, and 4) increased numbers of stressors such as noise, light and increased temperatures, which might
70 disrupt acoustic signalling and change immune responses. In addition, native species can be exposed to
71 competition with invasive amphibians (e.g., Gersava et al. 2020) and predation by introduced exotic species
72 such as crayfish or mosquitofish (Goodsell & Kats 1999, Riley et al. 2005). Urban anurans show higher
73 toxicant loads and greater physiological stress than non-urban anurans and other urban vertebrates (Murray
74 et al. 2019). Some species can thrive, others can take advantage without thriving and yet others may avoid
75 living in urban areas (i.e., urban exploiters, adapters and avoiders, respectively; Isaksson 2015). Because of
76 their specific dietary requirements and sensitive life stages, most amphibians are regarded as urban avoiders
77 (Isaksson 2015). However, anuran species may also respond in very different ways to urbanisation, ranging
78 from thriving and invading (Gersava et al. 2020) to disappearance of urban-sensitive species (Westgate et al.
79 2015). Examining different types of habitat alterations in eastern Argentina, similar habitat alterations were
80 shown to cause greater diet similarities independent of site location than different habitat alterations (López
81 et al. 2015). This indicates that urbanisation does not create the same effects on populations and species but
82 it is the specific types of anthropogenic habitat changes that result in specific changes in trophic niches.

83

84 Body condition is assumed to generally be reduced in altered landscapes as a consequence of anthropogenic
85 habitat changes (Brodeur et al. 2011). However, some anurans have been documented to be of larger body
86 size in urban settings than individuals of the same species in natural habitats, as in the case of the green frog
87 (*Pelophylax perezi*) studied in Spain (Iglesias-Carrasco et al. 2017). Prey availability and diet have been
88 hypothesized as one of several variables that can influence larger body size in birds (Shochat 2004) and in
89 amphibians (Iglesias-Carrasco et al. 2017). The latter authors observed increased densities of some exotic
90 invertebrate species in urban habitats and argued that an amphibious diet (including live insects, crustaceans
91 and worms) was advantageous for adapting to urban habitats because amphibians could more easily harvest
92 recently created exotic communities of invertebrates compared to other vertebrate groups. Habitat alterations
93 create changes in available prey for anurans in complex ways with different changes impacting different prey
94 taxa (e.g., Basset et al. 2008, López et al. 2015). Urban areas tend to have lower invertebrate prey availability
95 (Coleman & Barclay 2013) although there is a large variability depending on habitat composition
96 (Jaganmohan et al. 2013). Some species can adjust their diet composition to resource availability whilst
97 others cannot, whereby the first group may have an adaptive advantage in changing environments in general
98 and in urban landscapes in particular (López et al. 2015). For example, increases in ant populations because
99 of damming did not lead to increased consumption in tree frogs (López et al. 2015). Based on dietary
100 analysis of 57 individuals of the rufous frog *Leptodactylus fuscus* (family Leptodactylidae) in Brazil, Santana
101 et al. (2019) demonstrated that urban frogs focussed on eating Coleoptera while rural frogs had a more
102 diverse diet. To complicate matters, feeding plasticity may not be linked to the relatedness between species
103 as it may significantly differ between closely related species (López et al. 2015). Thus, sensitivities to
104 consequences of habitat changes following urbanisation are species-specific but remain unknown for most
105 amphibians, especially in the tropics.

106

107 Anurans of the family Bufonidae (true toads) include 52 genera that are distributed worldwide and inhabit a
108 variety of habitats, from deserts to tropical rainforests (e.g., Amphibian Survival Alliance 2021). The trophic
109 ecology of species within the Bufonidae has been widely studied throughout the world (e.g., Evans & Lampo
110 1996, Sabagh & Carvalho-e-Silva 2008, Duré et al. 2009, Maia-Carneiro et al. 2013, Flynn et al. 2021),
111 primarily suggesting that this group is made up of active foragers that search for and eat small, slow-moving
112 but highly aggregated prey, such as ants and termites (Toft, 1980,1981; Simon and Toft, 1991). However, the
113 feeding strategy of Bufonidae remains controversially discussed (Sabagh & Carvalho-e-Silva 2008) with
114 some authors classifying them as ant-specialists (Toft 1980, Isacch & Barg 2002) and others classify them as
115 generalists (Smith & Bragg 1949, Evans & Lampo 1996). Nonetheless, recent studies have argued that these
116 anurans have a mixed foraging strategy, only in part fitting that of typical active foragers (Crnobrnja-
117 Isailović et al. 2012). For example, the common toad (*Bufo bufo*) is neither a feeding generalist nor a
118 myrmecophagous specialist (i.e., specialized on ants and termites), as some bufonids are proclaimed to be
119 (Crnobrnja-Isailović et al. 2012). The very limited number of studies of Bufonidae in urban areas indicates
120 that the trophic ecology of toads in anthropogenic settings may change in response to differences in prey
121 availability and to the type and intensity of habitat changes caused by urbanisation. For example, European
122 green toads (*Bufo viridis*) preferentially consume insects attracted to artificial street lighting in urban
123 environments (Covaciu-Marcov et al. 2010). Green toads can also benefit from fallen fruits from trees
124 typically planted in urban and suburban localities, becoming an important food source just after
125 metamorphosis and also during the period of intensive growth preceding the first hibernation (Kaczmarek et
126 al. 2019). The Cururu toad *Rhinella diptycha* in Brazil is also reported to eat fruits in urban settings
127 (Severgnini et al. 2020). Fragmented wetlands and changes in habitat structure around wetlands and ponds
128 can also affect the diet composition and even body condition of resident anuran species (Mikoláš 2016). In
129 the tropics and subtropics, several anuran species are capable of adapting to urban or peri-urban habitats. In a
130 study in Accra, the capital of Ghana, Ofori et al. (2021) compared the diets of the African common toad
131 *Amietophrynus regularis* (now *Sclerophrys regularis*, Poynton et al., 2016) in urban and agricultural habitats.
132 Being an opportunistic generalist predator with a broad dietary niche there were no demonstrable dietary
133 differences between habitats.

134

135 In the present paper, we studied the trophic ecology of two adult stage Bufonidae species, the African
136 common toad (*S. regularis*) and the Hallowell's toad (*S. maculata*) in urban environments. These species are
137 ecologically and morphologically similar. We studied the food habits of the African common toad in Lomé
138 (Togo), Cotonou (Benin) and Ikeja (Lagos, Nigeria), and the Hallowell's toad in Port Harcourt and Ikeja
139 (both in Nigeria). Both species occurred sympatrically in Ikeja. The African common toad is a very abundant
140 species widely distributed along the Atlantic coast, from Senegal to Cameroon, Ethiopia and Kenya in the
141 East, and along the Nile valley from South Sudan to Egypt, and along a coastal strip between Cameroon and
142 Angola (Rödel, 2000). Preferred habitats are moist and dry savannahs, montane grassland, forest margins

143 and agricultural habitats, often in association with rivers (IUCN SSC Amphibian Specialist Group 2016a).
144 The Hallowell's toad is sympatric with the African common toad but restricted to an area ranging from
145 Senegal to Cameroon (IUCN SSC Amphibian Specialist Group 2016b). Hallowell's toad is also very
146 common, inhabiting a broad range of habitats including humid savannas, drier savannas along rivers, forest
147 edges, degraded forest and agricultural land (IUCN SSC Amphibian Specialist Group 2016b). Both toad
148 species are generalists that can also be found in anthropologically altered and fragmented habitats (Ernst et
149 al. 2006). Due to its ecological elasticity, the African common toad in Qatar can even survive in irrigation
150 pipes and water transportation vehicles (Abdulkarim & Yamaguchi 2021).

151

152 We investigated trophic niche breadth and explored (1) whether taxonomic diet composition of the two toads
153 varied within and between urban localities, (2) if local conditions (using rainfall as a proxy) and prey type
154 availability in the field affected diet similarity between the two toad species and (3) whether there were
155 differences in diet in comparison with similar species in non-urban locations. We also analysed whether
156 adult toad diets were affected by season (wet versus dry) and varied by sex. We hypothesised that because
157 both these toad species are highly adaptable, their diets would vary remarkably among study areas and toad
158 diets would be more similar between nearby sites than more distant ones.

159

160 **Materials and methods**

161

162 **Study areas**

163

164 We carried out the present study in four cities of three different West African countries: Lomé, the capital of
165 Togo, Cotonou, the economic centre of Benin, Ikeja, the capital of Lagos State in southwestern Nigeria, and
166 Port Harcourt, the capital of Rivers State in southeastern Nigeria. All four cities are situated near the Gulf of
167 Guinea coast. To minimize the effects of local habitat on diet composition, we selected sites with similar
168 characteristics, i.e., areas in the periphery of each city, with cement buildings surrounded by grassy patches
169 and small ornamental house gardens. Locations varied from Port Harcourt, situated inside the rainforest zone
170 of southern Nigeria, Ikeja at the border between the moist forest and the West African savannah zone, and
171 Cotonou and Lomé within the Dahomey Gap savannahs. Thus, although locally similar, the four study sites
172 were found in different vegetation zones.

173

174 **Toad diets**

175

176 Diet data were obtained from individuals found as (i) roadkills and (ii) from stomach flushing of live
177 individuals in night surveys. All animals were opportunistically collected over a period of 394 days across all
178 study areas: 133 during the wet season (April - September 2010-2020), and 261 in the dry season (October
179 and March 2010-2020). It took longer to collect an adequate sample size during the dry season because toads

180 of both species spend less active above-ground than in the wet season (unpublished observations),
181 influencing also the number of roadkills and live individuals available for examination.

182 Live animals were flushed within one hour from the capture, without any anaesthetising and using the
183 available potable water. The stomach flushing procedure followed Solé et al. (2005). Each toad was held
184 safely by fixing the forelimbs with one hand, and the water-filled tube attached syringe was held in the other.
185 We used a metal spatula to open the toad's mouth and then introduced the syringe tube through the
186 oesophagus into the stomach; the pyloric end of the stomach can normally be felt. The entire content of the
187 syringe was then flushed into the stomach and any content forced out collected in the vessel. The same
188 procedure was repeated until all the stomach contents were forced out. When no more stomach content
189 appeared after flushing, the animal was released to the wild. No animals were killed or damaged during the
190 stomach flushing procedure, and all individuals appeared in good conditions when released. Food contents
191 were fixed in 70% alcohol and then examined under a dissecting microscope. Stomach contents of recently
192 killed toads that were opportunistically collected in the various study areas, were also preserved in alcohol
193 before dissecting in the laboratory.

194

195 Dietary analyses of stomach contents did not include plant remains as they can be assumed to be secondarily
196 ingested by toads in some cases while foraging on live insects (e.g., Korschgen & Moyle 1955, Mahan &
197 Johnson 2007). Stomach contents of sampled toads were analysed using standard procedures (Solé & Rödder
198 2010). The taxonomical composition of the diet was determined by identifying, under a dissecting
199 microscope, the various parts of insects and other invertebrates to the highest taxonomic level possible. We
200 identified the various items to the level of superfamily (e.g., Vespoidea), class (e.g., Gastropoda), subclass
201 (e.g., Oligochaeta), infraorder (e.g., termites, i.e., Isoptera) or order (e.g., Order: Coleoptera, Lepidoptera).
202 Coleoptera and Lepidoptera were identified as larvae or adults.

203

204 We evaluated the abundance of arthropods that were actively moving on ground or flying close to the ground
205 level, assuming that these were the only invertebrate categories being readily available to toads. We used
206 entomological sweep-net sampling (Hirai & Matsui 2000) and sticky traps (Beard et al. 2003, 2021) to
207 determine arthropod abundance in Port Harcourt and Cotonou. Netting was carried out in four ten-minutes
208 zigzag transects within each city (two in the dry and two in the wet seasons). These were conducted in
209 microhabitats in the same nights in which toads were observed either alive during random observation
210 sessions, or after roadkills were collected. Sticky traps were randomly set in the same places where multiple
211 toad individuals were observed, under the assumption that toads concentrate in sites with higher potential
212 prey density. Sticky traps were vertically positioned at ground level, thus minimizing the risk of also
213 capturing toads by chance. In fact, only one toad was unintentionally trapped. In each study area, a total of
214 200 sticky traps per night were placed randomly at 18h00 and removed the next day at 06h00. Trapping was
215 carried out for three consecutive nights during each season, in each of the four study areas. Each sticky trap
216 was removed after the sampling night and replaced with another in the next trapping day. Data from sweep-

217 net transects and sticky trapping were combined for the analysis. We identified the taxonomical status of
 218 trapped individuals to the same taxonomic level as for the diet analysis.

219

220 **Statistical analyses**

221

222 Food niche overlap between toad populations was assessed using the Pianka's (1986) symmetric equation,
 223 with values ranging from 0 (no overlap) to 1 (total overlap):

$$224 \quad O_{xy} = \frac{\sum_{i=1}^n p_{xi} p_{yi}}{(\sum_{i=1}^n p_{xi}^2 \sum_{i=1}^n p_{yi}^2)^{1/2}}$$

225 where p_{xi} is the proportional utilization of prey i by population x and p_{yi} the proportional utilization of prey i
 226 by population y .

227

228 We also tested the effects of geography and local weather conditions on the inter-population food niche
 229 overlap. The geographic pattern was estimated by linear distance between pairs of study sites (in km).

230 Weather conditions were approximated by the mean annual rainfall as a proxy of the site-specific conditions
 231 using data on annual rainfall at each site from the Istituto Geografico de Agostini (2020). The difference in
 232 mean annual rainfall (in mm) between pairs of study sites was calculated as follows:

$$233 \quad \Delta_{\text{rainfall}} = \text{rainfall of the wetter place} - \text{rainfall of the drier place}$$

234

235 Since $(\log)\Delta_{\text{rainfall}}$ and $(\log)\text{distance}$ between pairs of sites were not significantly correlated ($r = 0.579$, $P =$
 236 0.229), these two variables were entered independently in the analyses. The effect of air temperature was not
 237 analysed because air temperatures were nearly identical among study areas throughout the year with a
 238 nocturnal mean of 28°C and a diurnal mean of 33°C (Istituto Geografico de Agostini 2020).

239

240 We evaluated whether our sample sizes captured the "true" prey category richness and diversity within each
 241 study site by (i) rarefaction analysis for species discoveries at each site with 95% confidence intervals of the
 242 estimates approximated by 9999 bootstraps simulations; and by (ii) calculating the Chao-1 index from
 243 abundance data (Chao 1984). This latter index represents the theoretical number of prey categories that can
 244 be expected on the basis of the sampling regime. In addition, the following univariate prey category diversity
 245 metrics were calculated for each site: (i) species richness (total number of species recorded in the diet of
 246 toads at each site); (ii) dominance, D ; (iii) Simpson index, S with $S = 1 - D$; (iv) Shannon entropy index, H'
 247 (Shannon & Weaver 1963); and (v) evenness, e , calculated by Buzan and Gibson's formula (Magurran
 248 1988). For each diversity metric, we also generated upper and lower 95% confidence intervals by bootstrap
 249 analysis with 9999 random samples, each with the same total number of individuals as in each original
 250 sample (Harper 1999). Food niche breadth of the various toad populations was evaluated by Simpson's
 251 (1949) diversity index, S .

252

253 All variables were tested for normality and homoscedasticity prior to applying parametric tests, and, if
254 required, log transformed to achieve normality. When normalization was impossible, we applied
255 nonparametric tests. Correlations between (1) linear distance between pairs of sites and food niche overlap,
256 and between (2) Δ_{rainfall} and food niche overlap were tested using the non-parametric Spearman's rank
257 correlation coefficient, r_s .

258

259 One-way Analysis of Similarities (ANOSIM) was used to test for significant inter-population differences
260 among diet compositions, based on Bray-Curtis distance measure and 10,000 permutations (Clarke 1993). In
261 this analysis, the distances were converted to ranks (Clarke 1993). ANOSIM analysis was performed in the R
262 statistical environment, using the Vegan package version 2.5-7 (Oksanen et al. 2020). A VARIMAX rotated
263 Principal Component Analysis, PCA, was applied to arrange the various toad populations within the
264 multivariate space in regard to their taxonomic diet composition. The VARIMAX rotation is an adjustment
265 of the PCA that maximizes the variance shared among items in order to better depict the relationship
266 amongst them (Kaiser 1958). This PCA was carried out using Statistica v. 8.0 (Statsoft). Frequency
267 differences in the occurrence of prey type categories in the diets of sympatric or allopatric toad species were
268 assessed by contingency table χ^2 tests. Frequency differences in the occurrence of prey type categories in the
269 diets of males versus females in the two study species, and between dry and wet seasons (all sites being
270 pooled in order to increase sample sizes) were assessed by contingency table χ^2 tests. Correlations between
271 prey resource availability and consumption by toads were assessed by Spearman's rank correlation
272 coefficient. Ivlev's electivity index and the forage ratio, two commonly used measures of food selection,
273 were not used because they are significantly biased when the sizes of the prey samples from the gut of the
274 predator and the habitat are unequal (Strauss, 1979) as it was in our case of study. All other analyses were
275 conducted using PAST 4, version 4.04, statistical package (Hammer 2020), with alpha being set at 5% and
276 all tests being two tailed.

277

278 **Results**

279

280 **Diets**

281

282 We examined the food contents of 146 toads, including 46 *S. maculata* from Port Harcourt, 33 *S. regularis*
283 from Cotonou, 13 *S. maculata* and 13 *S. regularis* from Ikeja (all inhabiting the same microhabitat and thus
284 being strictly sympatric) and 41 *S. regularis* from Lomé. The taxonomical composition of the diet of these
285 toad populations is given in Table 1. Rarefaction analysis confirmed that diet composition was satisfactorily
286 assessed in all study areas (Online Supplemental Figure S1).

287

288 Across all four cities, Formicoidea and Oligochaeta were by far the main food items (both categories eaten
 289 by 26.7% of the individuals), followed by Coleoptera adults (15.8%) and Coleoptera larvae (14.4%). All
 290 other prey categories were relatively rare. The diet composition of sympatric *S. maculata* and *S. regularis* in
 291 Ikeja did not differ significantly (contingency table $\chi^2 = 3.48$, $df = 9$, $p = 0.979$) and consisted mainly of
 292 Formicoidea (Figure 1). Food niche breadth was slightly higher in *S. maculata* ($B = 1.497$) than in *S.*
 293 *regularis* ($B = 1.208$), and the niche overlap was very high ($O = 0.976$). The taxonomic composition of the
 294 diet did not differ significantly among study areas in both *S. regularis* (contingency table $\chi^2 = 10.9$, $df = 11$,
 295 $p = 0.451$) and *S. maculata* ($\chi^2 = 22.1$, $df = 15$, $p = 0.104$). Because of this similar diet composition between
 296 the species, we pooled the data from the two species at Ikeja for further analyses.

297

298 There was a considerable variation in diet composition across populations: in terms of food niche breadth,
 299 Port Harcourt showed by far the greatest width ($B = 8.96$), followed by Cotonou ($B = 3.57$), Ikeja ($B = 2.59$)
 300 and Lomé ($B = 1.09$). Log values for food niche width and local rainfall were significantly positively
 301 correlated ($r = 0.997$, $n = 4$, $p < 0.001$). The mean dietary overlap between population pairs was relatively
 302 high ($O = 0.721$) but with a wide variation from 0.448 to 0.901. Maximum overlap was observed between
 303 Port Harcourt and Cotonou ($O = 0.901$) and the least between Lomé and Ikeja ($O = 0.448$). The **smallest**
 304 **dietary overlap observed for the latter cities corresponded with the greatest distances of the** qualitatively
 305 assessed degree of urbanisation. The linear distances between pairs of sites were not correlated with food
 306 niche overlap ($r_s = -0.03$, $p = 0.954$) and the same was observed for the $\Delta_{rainfall}$ ($r_s = -0.657$, $p = 0.136$).

307

308 Diversity profiles (Figure 2) showed that the Port Harcourt population's diet differed substantially from the
 309 Ikeja population. Dietary diversity metrics also revealed significant differences among sites (Table 2).
 310 Dominance was considerably higher in Ikeja than elsewhere, whereas the other three metrics were lower in
 311 Ikeja than in the other three sites. The toad population in Port Harcourt had the lowest dominance and the
 312 highest values for evenness, Simpson and Shannon indices (Table 2). Chao-1 index revealed that the Lomé
 313 population had a much wider potential dietary spectrum than all the other populations (Table 2).

314

315 The value of ANOSIM on the taxonomic composition of the diet in the four cities was significant (mean rank
 316 within groups = 5333; mean rank between groups = 7123; $p < 0.001$). The first two axes of the PCA
 317 explained 96.5% of the variance (PC1: 84.5%, PC2: 12%). Ikeja, Lomé and Port Harcourt were positioned
 318 about equidistantly in the multivariate space and Cotonou was intermediate to the latter two populations
 319 (Figure 3).

320

321 **Intersexual differences**

322

323 To determine sexual differences in diets (Online Supplemental Table S1) we examined 52 *S. maculata* (31
 324 females and 21 males) and 79 *S. regularis* (44 females and 35 males). The taxonomic units of the diet

325 composition did not differ significantly between sexes in *S. maculata* (contingency table $\chi^2 = 11.4$, $df = 11$, p
 326 $= 0.409$) and in *S. regularis* ($\chi^2 = 14.84$, $df = 14$, $p = 0.389$). Diversity metrics in both species revealed that
 327 females had a more varied diet, with higher evenness and lower dominance index values than males (Table
 328 3). The Chao-1 index predicted 15 (95% CI = 12-18) prey type categories for females and only 9.5 (95% CI
 329 $= 11-13.75$) for males, indicating that *S. maculata* females had a remarkably higher dietary taxonomic
 330 richness than males. The same trend was also present in *S. regularis*, but less pronounced and with more
 331 overlapping 95% CI intervals between the sexes (13.75, 8.38-19.13, versus 11.75, 5.75-17.75; Table 3).

332

333 In interspecific comparisons, *S. maculata* showed greater extremeness in trophic variability as indicated by
 334 the Chao-1 index with (i) *S. maculata* females having a potential trophic diversity greater than that of *S.*
 335 *regularis* females, and (ii) *S. maculata* males having less trophic diversity than those of *S. regularis* (Table
 336 3).

337

338 **Interseasonal differences**

339

340 Online Supplemental Table S2 summarises the dietary data by season and study area. Contingency table
 341 analysis showed that diet compositions differed significantly between seasons ($\chi^2 = 40.39$, $df = 15$, $p <$
 342 0.001), with Oligochaeta, Gastropoda and Coleoptera adults being eaten significantly more often by wet
 343 season whereas Formicoidea by dry season (at least $p < 0.0001$ in all pairwise comparisons at sequential χ^2
 344 tests). The frequencies of consumption of all the other prey categories did not differ significantly between
 345 seasons (at least $p > 0.05$ in all pairwise comparisons at sequential χ^2 tests). Table 4 presents the values of
 346 diversity metrics for the interseason variations. The values of the diversity metrics of the pooled populations
 347 were similar between seasons (Table 4) except for Chao-1, which predicted a much wider breadth of food
 348 type categories for the wet season than for the dry season (95% confidence intervals: 15.5-26.75 *versus* 11.5-
 349 17.5).

350

351 **Prey availability**

352

353 Online Supplemental Table S3 summarises prey availability by season and by study area (Cotonou and Port
 354 Harcourt). The overall number of recorded individuals of all taxa was higher in the wet season (1729 versus
 355 1610 in Cotonou and 3613 versus 3323 in Port Harcourt), and the frequencies of occurrence of the various
 356 prey types were higher by wet season at the two study areas (contingency table $\chi^2 = 1998$, $df = 57$, $p <$
 357 0.0001). The richness of available prey types was 20 taxa in the wet season and 15 taxa in the dry season.

358

359 In Port Harcourt, where we only recorded *S. maculata*, toads did not feed on the available prey type, both in
 360 the wet season ($r_s = 0.06$, $p = 0.811$) and the dry season ($r_s = 0.21$, $p = 0.369$). Equally in Cotonou, where
 361 we only recorded *S. regularis*, diet and food availability were not significantly correlated with each other for

362 the wet season ($r_s = -0.09$, $p = 0.703$) and the dry season ($r_s = 0.37$, $p = 0.097$). When we compared the
 363 observed frequencies of consumption of prey items by toads in relation to those expected on the basis of the
 364 availability of each food category in the field, we observed for both species and either seasons the following
 365 patterns (that were significant at $P < 0.05$ at χ^2 tests with $df = 1$): (i) toads tended to avoid eating on
 366 Collembola, Thysanoptera, Hemiptera and Homoptera despite being very abundant in the field; (ii) toads
 367 feed upon Gastropoda much more than their availability; and (iii) toads feed upon Formicoidea relative to
 368 their availability in the field. For all other prey type categories, no significant patterns emerged from our
 369 analyses.

370

371 Discussion

372

373 In this study we documented the diet differences of two relatively common toad species living in urban
 374 environments in several cities in West Africa. Our two study species have wide geographical distributions
 375 and are known to be habitat generalists. Both toads thrive in a variety of ecological conditions (IUCN SSC
 376 Amphibian Specialist Group 2016b, 2016a), and similarly to Ofori et al.'s (2021) study in Ghana we confirm
 377 that the two toad species occupy and thrive in urban habitats in other countries in West Africa. Significantly,
 378 we showed that the dietary composition of urban toads varied between populations; both species being able
 379 to exploit strictly terrestrial prey (e.g., Oligochaeta, Coleoptera larvae, Formicoidea) as well as flying prey
 380 (e.g., Vespoidea, Diptera). In all toad populations, the most frequently eaten foods were always terrestrial
 381 taxa (Formicoidea, Coleoptera adults and larvae, and Oligochaeta). Moreover, in two of the studied
 382 populations where we measured prey availability and diets, toads were actively targeting potential prey
 383 rather than opportunistically hunting them, since there was no correlation between prey availability and diets.
 384 This suggests that the studied toads are selective predators where foraging for terrestrial prey is the primary
 385 feeding strategy whereas consumption of flying organisms is only secondary. These findings contrast with
 386 other studies that suggest that in a number of studied anuran species (e.g., Cogălniceanu et al. 1998, Hirai &
 387 Matsui 1999, Heise-Pavlov & Longway 2011) opportunistic predation is the norm. This conclusion was also
 388 reached by Ofori et al. (2021) for *S. regularis* in urban and agricultural habitats in Ghana.

389

390 Some studies of have suggested that Bufonidae species are relatively specialized ant-feeders (e.g., Isacch &
 391 Barg 2002) especially in the tropics (Toft 1980, 1981), or else they concentrate on ants and beetles (Sulieman
 392 et al. 2016). Ants and beetles were indeed the main food types in *S. regularis* populations from Ghana (Ofori
 393 et al. 2021) but ants and Oligochaeta were more important for *S. maculata* in deforested areas of Akwa Ibom
 394 State in south-eastern Nigeria (Eniang et al. 2003). Beetles were prominent in the diet of another southern
 395 Nigerian population of *S. maculata* (Akani et al. 2011). However, as in Isacch and Barg (2002) we observed
 396 that *S. regularis* and *S. maculata* fed upon a wide variety of prey types; ants were the dominant prey type in
 397 one site (>80% of individuals containing them in their guts) and an important food source in the other three
 398 sites. Given these findings, it is not possible to corroborate the hypothesis that Bufonids are ant specialists

399 (Toft, 1980, 1981), more in line with the observations by Crnobrnja-Isailović et al. (2012) for the European
400 *Bufo bufo*. We conclude that in our study, toads were consuming ants relative to their availability, thus not
401 selected or preferred prey items. As indicated by Clarke (1974) the abundance of ants and beetles in
402 stomachs of studied toads simply reflects the abundance of these taxa in areas where the toads feed (Berry &
403 Bullock 1962, Klimstra & Myers 1965).

404

405 Differences in dietary metrics amongst the studied toads populations can be attributable to local ecological
406 characteristics. For instance, toad diets appeared to be affected by the degree of urbanisation. This is clearly
407 shown by the fact that diet diversity in Ikeja and Lomé, the most and the least urbanised of our study sites
408 respectively, were lowest and highest in all sites. Conversely, the linear distance between the populations
409 was not correlated with the respective food niche overlap. The non-effect of the linear distance between sites
410 on the food niche overlap between pairs of populations was counterintuitive. In fact, we would have
411 expected that nearby locations would also be characterized by a more similar availability of potential prey
412 than between more distant ones, with a consequent greater similarity in the diet of toad populations in nearby
413 locations. Moreover, the single population studied inside a tropical forest area (Port Harcourt) had a
414 significantly wider diet breadth than all other toad populations. Thus, we suggest that the available diversity
415 of potential prey was much higher in Port Harcourt than in the other cities (forest versus savannah patterns in
416 species diversities), although we did not carry out prey type availability surveys in Port Harcourt to confirm
417 this.

418

419 In both males and females of the two study species, diet composition was relatively similar in all sites
420 though females had a wider niche breadth than males. This result is consistent with data on *S. regularis* from
421 urban and agricultural habitats in Ghana (Ofori et al. 2021) and is likely due to intersexual differences in
422 body size, with females being significantly larger than males in both species (Rödel 2000). Although in
423 theory the larger body size may allow females to target specifically larger prey items than males, our data do
424 not confirm this prediction since we found no statistical intersexual differences in frequency of occurrence of
425 large prey items (e.g., Oligochaeta) in toad stomachs. Therefore, it can be speculated that the wider niche
426 breadth of females depends on additional small-to-medium size taxonomic categories than in males.
427 Although in other anurans the larger sex has a more varied diet composition (e.g., Magalhães et al. 2016),
428 this is not always the case. For example, in the European *Bufo bufo*, males consumed small prey items in
429 higher proportions than did females, but the opposite was true for medium-size prey, which suggests possible
430 dietary niche partitioning in prey size rather than in taxonomical dietary composition (Crnobrnja-Isailović et
431 al. 2012).

432

433 The values of Chao-1 index indicated that food niche breadth was substantially higher in the wet season than
434 in the dry season. This result is in concordance with the observed patterns of higher numbers of trapped
435 arthropods and trapped prey categories during the prey availability screens (Table 7). Sympatric

436 arthropodous vertebrates (lizards) showed also a much higher prey type diversity in the wet season
437 (Dendi et al. 2019) . It indicates that these patterns are linked to the seasonal fluctuating availability of
438 arthropods in tropical environments (Wolda 1978a, 1978b, 1980, e.g., Kishimoto-Yamada & Itioka 2015).
439 For example, in Tanzania, significant increases in insect density followed rains and were largely due to both
440 an increase in the number of individuals per species and an increase in the number of species (Denlinger
441 1980). The abundance of tephritid flies was also positively correlated with precipitations in Benin
442 (Gnanvossou et al. 2017). Toft (1980) suggested that in dry season food is less abundant and in short supply,
443 thus causing dietary changes in the feeding ecology of tropical anurans (including for instance enhancing
444 trophic niche partitioning among sympatric species).

445

446 **Conclusions**

447

448 In the tropics, species diversity is greater than in the subtropics and in temperate climates, and anurans have
449 more specialized diets, resulting in the structuring anuran communities (Toft 1980). Therefore, the observed
450 pattern of targeted prey consumption in *S. regularis* and *S. maculata* rather than the opportunistic prey
451 consumption observed in most anurans, might be an adaptation to high anuran diversity in the tropics rather
452 than an adaptation to urban habitats. Further comparisons between urban and un-disturbed habitats are
453 required to elucidate this question.

454

455 **Acknowledgements**

456

457 We thank G.H. Segniabeto from the University of Lomé for helpful advice during the execution of the
458 study. We are also grateful to two anonymous reviewers for their comments on the submitted draft.

459

460 **Financial support**

461

462 The Linnaeus Fund Research Award by the Chelonian Research Foundation (two grants to LL),
463 Conservation International (to LL) and the Turtle Conservation Fund (two grants to LL) financially
464 supported field research on West African species including the present study.

465

466 **Competing interests**

467

468 The author(s) declare none.

469

470 **Ethical statement**

471

472 The study species are not protected under any of the laws of the involved countries, and therefore no explicit
 473 authorization to carry out this study was required. In addition, the research protocol did not damage any
 474 individual on handling and used a procedure that has already been demonstrated to be safe for the handled
 475 subjects during previous studies. Ethical authorization was provided by the Institute for Development,
 476 Ecology, Conservation and Cooperation Ethical Committee.

477

478 ORCID

479 F. Petrozzi <https://orcid.org/0000-0002-5114-3816>480 G. C. Akani **N/A**481 E. A. Eniang **N/A**482 S. N. Ajong <https://orcid.org/0000-0002-7243-3580>483 S. M. Funk <https://orcid.org/0000-0001-7992-4115>484 J. E. Fa <https://orcid.org/0000-0002-3611-8487>485 N. Amadi <https://orcid.org/0000-0002-1200-0492>486 D. Dendi <https://orcid.org/0000-0003-1417-9091>487 L. Luiselli <https://orcid.org/0000-0001-6878-2916>

488

489

References

490

491 ABDULKARIM, A. & YAMAGUCHI, N. 2021. How does an alien amphibian expand its distribution in an
 492 hyper-arid environment?: African common toad (*Sclerophrys regularis*) in Qatar. *Journal of Arid*
 493 *Environments* 184:104250.

494 AKANI, G. C., LUISELLI, L., AMUZIE, C. C. & WOKEM, G. N. 2011. Helminth community structure and
 495 diet of three Afrotropical anuran species: a test of the interactive-versus-isolationist parasite
 496 communities hypothesis. *Web Ecology* 11:11–19.

497 AMPHIBIAN SURVIVAL ALLIANCE. 2021. Amphibiaweb, <https://amphibiaweb.org/index.html>.

498 BARBAULT, R. 1974. La régime alimentaire des amphibiens de la savane de Lamto. *Bulletin de l'Institute*
 499 *français d'Afrique noire. Série A, Sciences naturelles* 36:952–972.

500 BASSET, Y., MISSA, O., ALONSO, A., MILLER, S. E., CURLETTI, G., DE MEYER, M., EARDLEY, C.,
 501 LEWIS, O. T., MANSELL, M. W., NOVOTNY, V. & WAGNER, T. 2008. Changes in Arthropod
 502 Assemblages along a Wide Gradient of Disturbance in Gabon. *Conservation Biology* 22:1552–1563.

503 BEARD, K. H., DURHAM, S. L., WILLIG, M. R. & ZIMMERMAN, J. K. 2021. Lizard and frog removal
 504 increases spider abundance but does not cascade to increase herbivory. *Biotropica* 53:681–692.
 505 Wiley Online Library.

506 BEARD, K. H., ESCHTRUTH, A. K., VOGT, K. A., VOGT, D. J. & SCATENA, F. N. 2003. The effects of
 507 the frog *Eleutherodactylus coqui* on invertebrates and ecosystem processes at two scales in the
 508 Luquillo Experimental Forest, Puerto Rico. *Journal of Tropical Ecology*:607–617. JSTOR.

- 509 BERRY, P. Y. & BULLOCK, J. A. 1962. The food of the common Malayan toad, *Bufo melanostictus*
 510 Schneider. *Copeia*:736–741. JSTOR.
- 511 BRANDÃO, R. A., FENKER, J., LOPES, B. E. P. DE C., DE SENA, V. M. DE A. & VASCONCELOS, B.
 512 D. 2020. Diet of terrestrial anurans in an ephemeral and simplified habitat during the dry season in
 513 the Brazilian Cerrado. *Ethology Ecology & Evolution* 32:527–550. Taylor & Francis.
- 514 BRODEUR, J. C., SUAREZ, R. P., NATALE, G. S., RONCO, A. E. & ELENA ZACCAGNINI, M. 2011.
 515 Reduced body condition and enzymatic alterations in frogs inhabiting intensive crop production
 516 areas. *Ecotoxicology and Environmental Safety* 74:1370–1380.
- 517 CHAO, A. 1984. Nonparametric Estimation of the Number of Classes in a Population. *Scandinavian Journal*
 518 *of Statistics* 11:265–270.
- 519 CLARKE, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. *Austral*
 520 *Ecology* 18:117–143.
- 521 CLARKE, R. D. 1974. Food habits of toads, genus *Bufo* (Amphibia: Bufonidae). *American Midland*
 522 *Naturalist*:140–147. JSTOR.
- 523 COGĂLNICEANU, D., AIOANEI, F., CIUBUC, C. & VĂDINEANU, A. 1998. Food and feeding habits in
 524 a population of common spadefoot toads. *Alytes* 15:145–157.
- 525 COLEMAN, J. L. & BARCLAY, R. M. R. 2013. Prey availability and foraging activity of grassland bats in
 526 relation to urbanization. *Journal of Mammalogy* 94:1111–1122.
- 527 COVACIU-MARCOV, S.-D., CUPSA, D., FERENTI, S., DAVID, A. & DIMANCEAS, N. 2010. Human
 528 influence or natural differentiation in food composition of four Amphibian species from Histria
 529 Fortress, Romania. *Acta Zoologica Bulgarica* 62:307–313.
- 530 CRNOBRNJA-ISAILOVIĆ, J., ĆURČIĆ, S., STOJADINOVIĆ, D., TOMAŠEVIĆ-KOLAROV, N.,
 531 ALEKSIĆ, I. & TOMANOVIĆ, Ž. 2012. Diet composition and food preferences in adult common
 532 toads (*Bufo bufo*)(Amphibia: Anura: Bufonidae). *Journal of Herpetology* 46:562–567. BioOne.
- 533 DENDI, D., SEGNIAGBETO, G. H., DI VITTORIO, M. & LUISELLI, L. 2019. Are diet diversity metrics
 534 influenced more by rainfall or by temperature in an Afrotropical Scincid Lizard? *Ecological*
 535 *Research* 34:68–73. Wiley Online Library.
- 536 DENLINGER, D. L. 1980. Seasonal and annual variation of insect abundance in the Nairobi National Park,
 537 Kenya. *Biotropica*:100–106. JSTOR.
- 538 DURÉ, M. I., KEHR, A. I. & SCHAEFER, E. F. 2009. Niche overlap and resource partitioning among five
 539 sympatric bufonids (Anura, Bufonidae) from northeastern Argentina. *Phyllomedusa: Journal of*
 540 *Herpetology* 8:27–39.
- 541 ENABULELE, E. E. & AISIEN, M. S. O. 2012. Diets of *Hemisus mamoratus* and *Leptopelis hyloides* (order
 542 anura) from monoculture plantations in southern Nigeria. *Zoologist* 10:48–52.
- 543 ENIANG, E. A., KING, R., LEA, J., CAPIZZI, D. & LUISELLI, L. 2003. Trophic niches of four sympatric
 544 rainforest anurans from southern Nigeria: Does resource partitioning play a role in structuring the

- 545 community? *Revue d'écologie*. Société nationale de protection de la nature et d'acclimatation de
 546 France
- 547 ERNST, R., LINSENMAIR, K. E. & RÖDEL, M.-O. 2006. Diversity erosion beyond the species level:
 548 Dramatic loss of functional diversity after selective logging in two tropical amphibian communities.
 549 *Biological Conservation* 133:143–155.
- 550 EVANS, M. & LAMPO, M. 1996. Diet of *Bufo marinus* in Venezuela. *Journal of Herpetology* 30:73–76.
- 551 FLYNN, C. N., ARAÚJO, P. G. & ROCHA, C. F. D. 2021. Diet and microhabitat use by juveniles *Rhinella*
 552 *ornata* (Anura, Bufonidae) in an insular Brazilian Atlantic Rainforest area. *Brazilian Journal of*
 553 *Biology* 81:1129–1131. SciELO Brasil.
- 554 GERSAVA, J. R., ABAD, R., CAMÍNO, F., RESPONTE, M., ACHONDO, M. J. M. & GAMALO, L. E.
 555 2020. Native and invasive alien anuran species in urbanized areas in Davao City, Philippines, with
 556 preliminary study of feeding biology. *Biological Diversity and Conservation* 13:1–8.
- 557 GNANVOSSOU, D., HANNA, R., GOERGEN, G., SALIFU, D., TANGA, C. M., MOHAMED, S. A. &
 558 EKESI, S. 2017. Diversity and seasonal abundance of tephritid fruit flies in three agro-ecosystems in
 559 Benin, West Africa. *Journal of Applied Entomology* 141:798–809. Wiley Online Library.
- 560 GOODSSELL, J. A. & KATS, L. B. 1999. Effect of introduced mosquitofish on Pacific treefrogs and the role
 561 of alternative prey. *Conservation Biology* 13:921–924. Wiley Online Library.
- 562 HAMMER, Ø. 2020. Past 4. Natural History Museum, University of Oslo.
- 563 HEISE-PAVLOV, S. R. & LONGWAY, L. J. 2011. Diet and dietary selectivity of cane toads (*Rhinella*
 564 *marina*) in restoration sites: a case study in Far North Queensland, Australia. *Ecological*
 565 *Management & Restoration* 12:230–233. Wiley Online Library.
- 566 HIRAI, T. & MATSUI, M. 1999. Feeding habits of the pond frog, *Rana nigromaculata*, inhabiting rice fields
 567 in Kyoto, Japan. *Copeia*:940–947. JSTOR.
- 568 HIRAI, T. & MATSUI, M. 2000. Ant specialization in diet of the narrow-mouthed toad, *Microhyla ornata*,
 569 from Amamiyoshima Island of the Ryukyu Archipelago. *Current Herpetology* 19:27–34.
- 570 HIRSCHFELD, M. & RÖDEL, M.-O. 2011. The diet of the African Tiger Frog, *Hoplobatrachus occipitalis*,
 571 in northern Benin. *Salamandra* 47:125–132.
- 572 HUCKEMBECK, S., WINEMILLER, K. O., LOEBMANN, D. & GARCIA, A. M. 2018. Trophic Ecology
 573 of Two Sympatric Frogs with Contrasting Morphology and Habitat Use in a Subtropical Wetland.
 574 *Herpetologica* 74:207–216.
- 575 IGLESIAS-CARRASCO, M., MARTÍN, J. & CABIDO, C. 2017. Urban habitats can affect body size and
 576 body condition but not immune response in amphibians. *Urban Ecosystems* 20:1331–1338.
- 577 ISACCH, J. P. & BARG, M. 2002. Are bufonid toads specialized ant-feeders? A case test from the
 578 Argentinian flooding pampa. *Journal of Natural History* 36:2005–2012. Taylor & Francis.
- 579 ISAKSSON, C. 2015. Urbanization, oxidative stress and inflammation: a question of evolving, acclimatizing
 580 or coping with urban environmental stress. *Functional Ecology* 29:913–923.

- 581 ISTITUTO GEOGRAFICO DE AGOSTINI. 2020. Atlante geografico metodico. Istituto Geografico De
582 Agostini, Novara.
- 583 IUCN SSC AMPHIBIAN SPECIALIST GROUP. 2016a. *Sclerophrys regularis*, African Common Toad.
584 IUCN.
- 585 IUCN SSC AMPHIBIAN SPECIALIST GROUP. 2016b. *Sclerophrys maculata*, Hallowell's Toad. IUCN.
- 586 JAGANMOHAN, M., VAILSHERY, L. & NAGENDRA, H. 2013. Patterns of Insect Abundance and
587 Distribution in Urban Domestic Gardens in Bangalore, India. *Diversity* 5:767–778.
- 588 KACZMARSKI, M., TRYJANOWSKI, P. & KUBICKA, A. M. 2019. Urban plums and toads: do fleshy
589 fruits affect the post-metamorphic growth of amphibians? *PeerJ* 7:e6337.
- 590 KAISER, H. F. 1958. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* 23:187–
591 200. Springer.
- 592 KISHIMOTO-YAMADA, K. & ITIOKA, T. 2015. How much have we learned about seasonality in tropical
593 insect abundance since Wolda (1988)? *Entomological Science* 18:407–419. Wiley Online Library.
- 594 KLIMSTRA, W. D. & MYERS, C. W. 1965. Foods of the toad, *Bufo woodhousei fowleri* Hinckley. *Trans.*
595 *Ill. State Acad. Sci* 58:11–26.
- 596 KONOWALIK, A., NAJBAR, A., KONOWALIK, K., DYLEWSKI, Ł., FRYDLEWICZ, M., KISIEL, P.,
597 STARZECKA, A., ZALEŚNA, A. & KOLENDA, K. 2020. Amphibians in an urban environment: a
598 case study from a central European city (Wrocław, Poland). *Urban Ecosystems* 23:235–243.
- 599 KORSCHGEN, L. J. & MOYLE, D. L. 1955. Food habits of the bullfrog in central Missouri farm ponds.
600 *American Midland Naturalist*:332–341. JSTOR.
- 601 KOVÁCS, T., TÖRÖK, J., & GIESON, W. 1995. Dietary responses by edible frog (*Rana esculenta*
602 complex) to wetland habitat change in Hungary. Pp. 79–86 *Wetlands, Biodiversity and Development.*
603 *Proceeding of Workshop II of the International Conference on Wetlands and Development.* Wetlands
604 International, Kuala Lumpur, Malaysia.
- 605 LÓPEZ, J. A., SCARABOTTI, P. A. & GHIRARDI, R. 2015. Amphibian trophic ecology in increasingly
606 human-altered wetlands. *Herpetological Conservation and Biology* 10:819–832.
- 607 MAGALHÃES, R. F., GARDA, A. A., MARQUES, N. C. S. & BRANDAO, R. A. 2016. Sexual
608 dimorphism and resource utilisation by the Veadeiros waterfall frog *Bokermannohyla pseudopseudis*
609 (Anura: Hylidae). *Salamandra* 52:171–177.
- 610 MAGURRAN, A. E. 1988. Ecological diversity and its measurement. Princeton University Press, Princeton,
611 New Jersey.
- 612 MAHAN, R. D. & JOHNSON, J. R. 2007. Diet of the gray treefrog (*Hyla versicolor*) in relation to foraging
613 site location. *Journal of Herpetology* 41:16–23. BioOne.
- 614 MAIA-CARNEIRO, T., KIEFER, M. C., VAN SLUYS, M. & DUARTE ROCHA, C. F. 2013. Feeding
615 habits, microhabitat use, and daily activity period of *Rhinella ornata* (Anura, Bufonidae) from
616 three Atlantic rainforest remnants in southeastern Brazil. *North-Western Journal of Zoology* 9:157–
617 165.

- 618 MIKOLÁŠ, P. 2016. Can Change of Landscape Composition Increase Interspecies Competition Among
619 Amphibians and Thus Decrease the Body Condition of the Endangered *Bombina variegata*? *Polish*
620 *Journal of Environmental Studies* 25:2527–2531.
- 621 MORENO-BARBOSA, S. E. & HOYOS-HOYOS, J. 2014. Ontogeny of the diet in anurans (Amphibia)
622 collected at la vieja river basin in the departamento of Quindio (Colombia). *Caldasia* 36:365–372.
623 Instituto de Ciencias Naturales, Facultad de Ciencias-Universidad Nacional
- 624 MURRAY, M. H., SÁNCHEZ, C. A., BECKER, D. J., BYERS, K. A., WORSLEY-TONKS, K. E. &
625 CRAFT, M. E. 2019. City sicker? A meta-analysis of wildlife health and urbanization. *Frontiers in*
626 *Ecology and the Environment* 17:575–583.
- 627 OFORI, B. Y., MENSAH, J. B., ANDERSON, R. S. & ATTUQUAYEFIO, D. K. 2021. Diet composition,
628 body condition and sexual size dimorphism of the common African toad (*Amietophrynus regularis*)
629 in urban and agricultural landscape. *bioRxiv*. Cold Spring Harbor Laboratory.
- 630 OKSANEN, J., BLANCHET, F. G., KINDT, R., LEGENDRE, P., MINCHIN, P. R., O’HARA, R. B.,
631 SIMPSON, G. L., SOLYMOS, P., STEVENS, M. H. H. & WAGNER, H. 2020. Package ‘vegan’
632 (Community Ecology Package).
- 633 ONADEKO, A. B. 2011. Food and feeding habits of some anuran species in south-western Nigeria.
634 *Zoologist (The)* 9:57–69.
- 635 PARMELEE, J. R. 1999. Trophic ecology of a tropical anuran assemblage. Natural History Museum,
636 University of Kansas.
- 637 PIANKA, E. R. 1986. Ecology and Natural History of Desert Lizards Princeton University Press. *Princeton,*
638 *New Jersey*.
- 639 PIATTI, L. & SOUZA, F. L. 2011. Diet and resource partitioning among anurans in irrigated rice fields in
640 Pantanal, Brazil. *Brazilian Journal of Biology* 71:653–661. SciELO Brasil.
- 641 POYNTON, J. C., LOADER, S. P., CONRADIE, W., RÖDEL, M.-O. & LIEDTKE, H. C. 2016.
642 Designation and description of a neotype of *Sclerophrys maculata* (Hallowell, 1854), and
643 reinstatement of *S. pusilla* (Mertens, 1937) (Amphibia: Anura: Bufonidae). *Zootaxa* 4098:73.
- 644 RILEY, S. P. D., BUSTEED, G. T., KATS, L. B., VANDERGON, T. L., LEE, L. F. S., DAGIT, R. G.,
645 KERBY, J. L., FISHER, R. N. & SAUVAJOT, R. M. 2005. Effects of Urbanization on the
646 Distribution and Abundance of Amphibians and Invasive Species in Southern California Streams.
647 *Conservation Biology* 19:1894–1907.
- 648 RÖDEL, M. O. 2000. Herpetofauna of West Africa. Amphibians of the Western Savannah. *Frankfurt am*
649 *Main, Germany, chimaira edition*.
- 650 RUBBO, M. J. & KIESECKER, J. M. 2005. Amphibian Breeding Distribution in an Urbanized Landscape.
651 *Conservation Biology* 19:504–511.
- 652 SABAGH, L. T. & CARVALHO-E-SILVA, A. M. P. T. 2008. Feeding overlap in two sympatric species of
653 *Rhinella* (Anura: Bufonidae) of the Atlantic Rain Forest. *Revista Brasileira de Zoologia* 25:247–253.

- 654 SANTANA, D. J., FERREIRA, V. G., CRESTANI, G. N. & NEVES, M. O. 2019. Diet of the Rufous Frog
 655 *Leptodactylus fuscus* (Anura, Leptodactylidae) from two contrasting environments. *Herpetozoa*
 656 32:1–6.
- 657 SEVERGNINI, M. R., MOROTI, M. DE T., PEDROZO, M., CERON, K. & SANTANA, D. J. 2020.
 658 Acerola fruit: An unusual food item for the Cururu toad *Rhinella diptycha* (Cope, 1862) (Anura:
 659 Bufonidae). *Herpetology Notes* 13:7–10.
- 660 SHANNON, C. E. & WEAVER, W. 1963. The mathematical theory of communication. University of
 661 Illinois Press, Urbana, Illinois.
- 662 SHOCHAT, E. 2004. Credit or Debit? Resource Input Changes Population Dynamics of City-Slicker Birds.
 663 *Oikos* 106:622–626.
- 664 SIMPSON, E. H. 1949. Measurement of Diversity. *Nature* 163:688–688.
- 665 SMALLBONE, L. T., LUCK, G. W. & WASSENS, S. 2011. Anuran species in urban landscapes:
 666 Relationships with biophysical, built environment and socio-economic factors. *Landscape and*
 667 *Urban Planning* 101:43–51.
- 668 SMITH, C. C. & BRAGG, A. N. 1949. Observations on the ecology and natural history of Anura, VII. Food
 669 and feeding habits of the common species of toads in Oklahoma. *Ecology* 30:333–349. JSTOR.
- 670 SOLÉ, M., BECKMANN, O., PELZ, B., KWET, A. & ENGELS, W. 2005. Stomach-flushing for diet
 671 analysis in anurans: an improved protocol evaluated in a case study in Araucaria forests, southern
 672 Brazil. *Studies on Neotropical Fauna and Environment* 40:23–28. Taylor & Francis.
- 673 SOLÉ, M. & RÖDDER, D. 2010. Dietary assessments of adult amphibians. Pp. 67–84 in Dodd Jr., C. K.
 674 (ed.). *Amphibian Ecology and Conservation—A Handbook of Techniques*. Oxford University Press,
 675 Oxford, UK.
- 676 SULIEMAN, Y., PENGSAKUL, T. & AFIFI, A. 2016. Diet composition of the subdesert toad,
 677 *Amietophrynus xeros* (Anura: Bufonidae) in Sudan, North Africa. *Herpetological Conservation and*
 678 *Biology* 11:350–354.
- 679 TALIONE SABAGH, L., CARVALHO-E-SILVA, A. M. P. T. & ROCHA, C. F. D. 2012. Diet of the toad
 680 *Rhinella icterica* (Anura: Bufonidae) from Atlantic Forest Highlands of southeastern Brazil. *Biota*
 681 *Neotropica* 12:258–262. SciELO Brasil.
- 682 TOFT, C. A. 1980. Feeding ecology of thirteen syntopic species of anurans in a seasonal tropical
 683 environment. *Oecologia* 45:131–141. Springer.
- 684 TOFT, C. A. 1981. Feeding ecology of Panamanian litter anurans: patterns in diet and foraging mode.
 685 *Journal of herpetology*:139–144. JSTOR.
- 686 TOFT, C. A. 1985. Resource partitioning in amphibians and reptiles. *Copeia*:1–21. JSTOR.
- 687 TOHÉ, B., KOUAMÉ, N. G., ASSEMIAN, N. E. & GOURÈNE, G. 2015. Diet of two sympatric rocket
 688 frogs (Amphibia, Anura, Ptychadenidae: Ptychadena) in the disturbed parts of a West African
 689 rainforest. *International Journal of Innovative Science, Engineering & Technology* 2:444–459.

- 690 VIGNOLI, L. & LUISELLI, L. 2012. Dietary relationships among coexisting anuran amphibians: a
691 worldwide quantitative review. *Oecologia* 169:499–509.
- 692 WESTGATE, M. J., SCHEELE, B. C., IKIN, K., HOEFER, A. M., BEATY, R. M., EVANS, M.,
693 OSBORNE, W., HUNTER, D., RAYNER, L. & DRISCOLL, D. A. 2015. Citizen Science Program
694 Shows Urban Areas Have Lower Occurrence of Frog Species, but Not Accelerated Declines. *PLOS*
695 *ONE* 10:e0140973.
- 696 WOLDA, H. 1978a. Fluctuations in abundance of tropical insects. *The American Naturalist* 112:1017–1045.
697 University of Chicago Press.
- 698 WOLDA, H. 1978b. Seasonal fluctuations in rainfall, food and abundance of tropical insects. *The Journal of*
699 *Animal Ecology*:369–381. JSTOR.
- 700 WOLDA, H. 1980. Seasonality of tropical insects. *The Journal of Animal Ecology*:277–290. JSTOR.
- 701
- 702

703 **Table 1** Diet composition of toad individuals in four West African cities. Shown are the numbers of
 704 toads containing a given prey item (No.) and the percentage of toad stomachs containing that given
 705 prey item. The percentages are calculated on the basis of the total number of individuals examined
 706 per species (46, 33, 26, 41 for the four study areas, respectively). Note that the total sum of the
 707 numbers in each city exceeds the total number of toads examined as single stomachs could contain
 708 more than one prey item type. Data for the two *Sclerophrys* species are pooled for Ikeja, as there
 709 were no significant interspecific differences (see the main text); their species-specific diets are
 710 given in Figure 2.

711

	Port Harcourt (<i>S. maculata</i>)		Cotonou (<i>S. regularis</i>)		Ikeja (sympatric)		Lomé (<i>S. regularis</i>)	
	No.	%	No.	%	No.	%	No.	%
Oligochaeta	11	23.9	12	36.4	2	7.7	14	34.2
Gastropoda	0	0	1	3.0	5	19.2	7	17.1
Isopoda	0	0	0	0	1	3.8	0	0
Araneidae	13	28.3	5	15.1	1	3.8	0	0
Chilopoda	0	0	0	0	0	0	1	2.4
Coleoptera adults	11	23.9	7	21.2	2	7.7	3	7.3
Coleoptera larvae	14	30.4	7	21.2	0	0	0	0
Lepidoptera adults	0	0	1	3.0	0	0	1	2.4
Lepidoptera larvae	5	10.9	1	3.0	0	0	5	12.2
Vespoidea	3	6.5	1	3.0	1	3.8	2	4.8
Apoidea	2	4.3	0	0	1	3.8	0	0
Formicoidea	7	15.2	6	18.2	21	80.8	5	12.2
Dermaptera	0	0	2	6.1	0	0	0	0
Blattodea	8	17.4	3	9.1	2	7.7	0	0
Mantoidea	0	0	0	0	1	3.8	0	0
Diptera	4	8.7	4	12.1	0	0	0	0
Isoptera	0	0	0	0	0	0	1	2.4

712

713

714 **Table 2** Diversity indices for the diet composition for each city. 95% confidence intervals (CI) were calculated using 9,999 bootstrap simulations.

715 Data for the two *Sclerophys* species are pooled for Ikeja.

716

	Port Harcourt (<i>S. maculata</i>)			Cotonou (<i>S. regularis</i>)			Ikeja (sympatric)			Lomé (<i>S. regularis</i>)		
	Estimate	Lower CI	Upper CI	Estimate	Lower CI	Upper CI	Estimate	Lower CI	Upper CI	Estimate	Lower CI	Upper CI
Prey type richness	10	10	10	11	10	11	10	7	10	10	9	10
Dominance	0.1272	0.1183	0.1631	0.1395	0.1195	0.2012	0.3528	0.2316	0.5457	0.2032	0.1506	0.3097
Simpson	0.8728	0.8369	0.8817	0.8605	0.7988	0.8805	0.6472	0.4543	0.7684	0.7968	0.6903	0.8494
Shannon	2.157	1.988	2.207	2.135	1.907	2.238	1.553	1.029	1.84	1.87	1.593	2.067
Evenness	0.8645	0.7303	0.9086	0.7688	0.6303	0.8534	0.4726	0.3704	0.6465	0.6487	0.5147	0.7901
Chao-1	10	10	11	12.5	10.5	17	12.5	7.5	25	20	9.75	20

717

718 **Table 3** Diversity indices of diet composition of males and females of two toad species. 95% confidence intervals (CI) were calculated using 9,999
 719 bootstrap simulations. Data are pooled for each species across populations.

	<i>S. maculata</i>						<i>S. regularis</i>					
	females	Lower CI	Upper CI	males	Lower CI	Upper CI	females	Lower CI	Upper CI	males	Lower CI	Upper CI
Prey type richness	12	12	12	9	9	9	13	12	14	11	9	12
Dominance	0.117	0.089	0.144	0.145	0.114	0.175	0.144	0.103	0.186	0.163	0.107	0.220
Simpson	0.883	0.856	0.911	0.855	0.825	0.886	0.856	0.814	0.897	0.837	0.780	0.893
Shannon	2.279	2.150	2.408	2.015	1.894	2.137	2.197	2.006	2.388	2.050	1.830	2.270
Evenness	0.814	0.716	0.912	0.834	0.738	0.930	0.692	0.579	0.805	0.707	0.588	0.825
Chao-1	15	12	18	9.5	8	11	13.750	8.375	19.130	11.750	5.750	17.750

720

721 **Table 4** Diversity indices for seasonal diet composition for each city. 95% confidence intervals (CI)
 722 were calculated using 9,999 bootstrap simulations. Data are pooled for each species across
 723 populations.

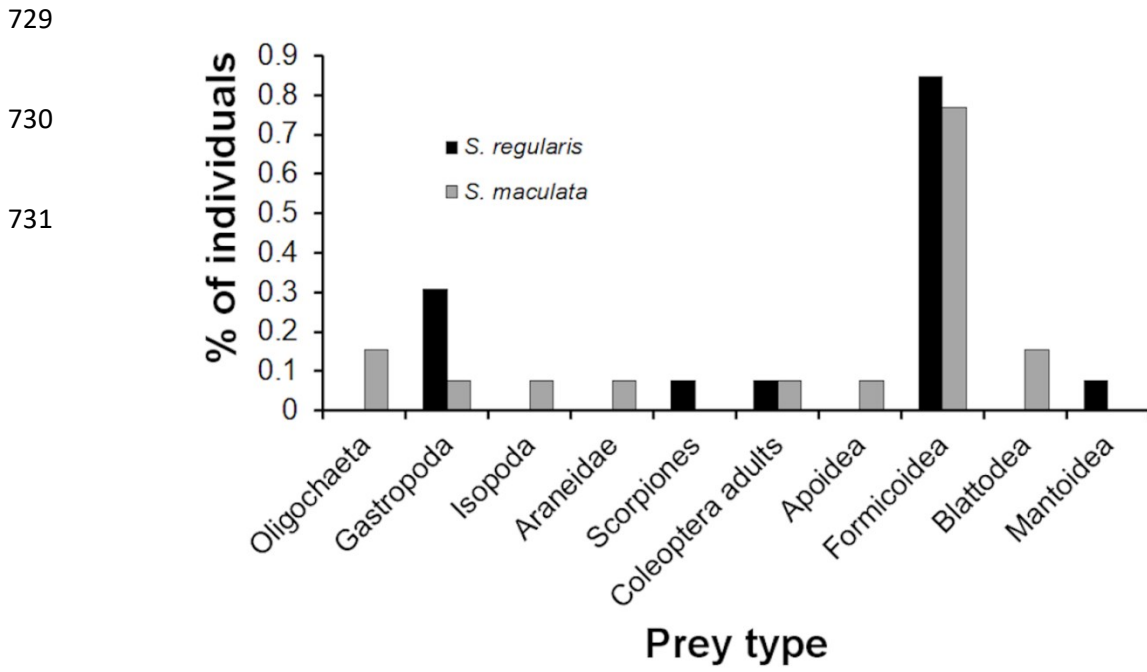
724

	Wet season	Lower CI	Upper CI	Dry season	Lower CI	Upper CI
Prey type richness	15	14	16	13	13	13
Dominance	0.142	0.1067	0.1772	0.1479	0.1092	0.1867
Simpson	0.858	0.8229	0.8932	0.8521	0.8133	0.8908
Shannon	2.244	2.091	2.397	2.181	2.037	2.324
Evenness	0.6287	0.5412	0.7161	0.6808	0.5838	0.7778
Chao-1	21	15.25	26.75	14.5	11.5	17.5

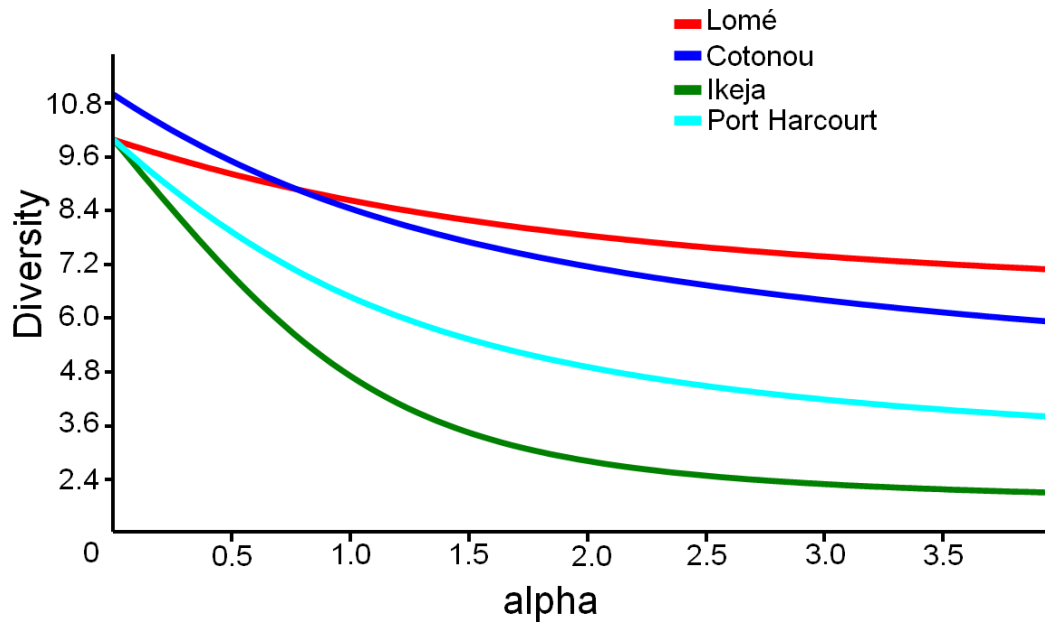
725

726

727 **Figure 1** Diet composition of sympatric toads in Ikeja (Lagos). For each species, 13 individuals
728 were analysed.



732 **Figure 2** Diversity profiles for prey category discoveries in relationship to sample size in stomachs
733 of *Sclerophrys regularis* and *S. maculata* for four urban study areas in West Africa.

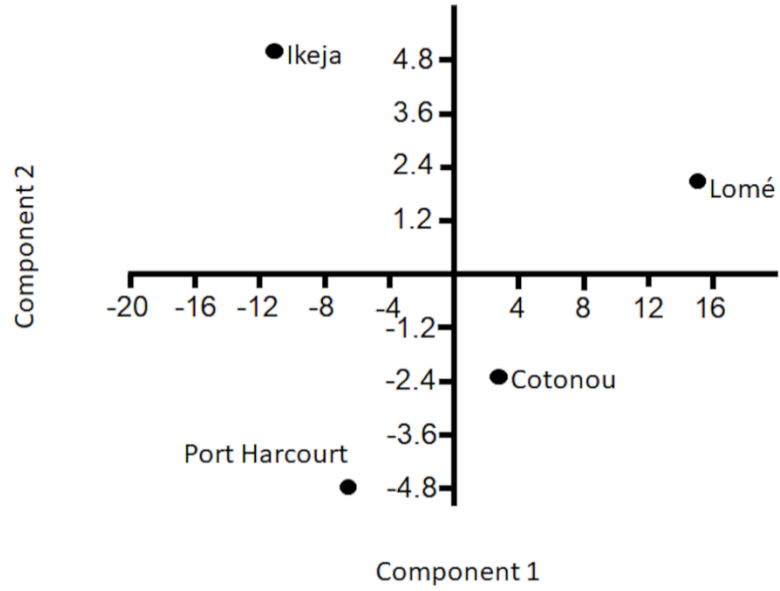


734

735 **Figure 3** Principal Component Analysis, PCR, with VARIMAX rotation of diversity index values
736 for toad populations in four West African cities.

737

738



739 **Online Supplementary Materials**

740 **Table S1** Intersexual differences in diet composition of the two studied toad in four West African
 741 cities. Data from all populations are pooled for each species. Percentage of stomachs containing that
 742 given prey item are relative to the total number of individuals per species.

	<i>S. maculata</i>				<i>S. regularis</i>			
	females (n=31)		males (n=21)		females (n=44)		males (n=35)	
		%		%		%		%
Oligochaeta	5	16.1	8	38.1	12	27.3	14	40
Gastropoda	1	3.2	0	0.0	3	6.8	5	14.3
Isopoda	1	3.2	0	0.0	0	0.0	0	0.0
Araneidae	7	22.6	7	33.3	4	9.1	1	2.9
Chilopoda	0	0.0	0	0.0	1	2.3	0	0.0
Coleoptera adults	7	22.6	5	23.8	8	18.2	6	17.1
Coleoptera larvae	6	19.4	8	38.1	2	4.5	5	14.3
Lepidoptera adults	0	0.0	0	0.0	1	2.3	0	0.0
Lepidoptera larvae	4	12.9	1	4.8	4	9.1	2	5.7
Vespoidea	3	9.7	1	4.8	3	6.8	0	0.0
Apoidea	1	3.2	2	9.5	0	0.0	0	0.0
Formicoidea	11	35.5	6	28.6	14	31.8	8	22.9
Dermaptera	0	0.0	0	0.0	2	4.5	0	0.0
Blattodea	4	12.9	6	28.6	1	2.3	2	5.7
Mantoidea	0	0.0	0	0.0	0	0.0	1	2.9
Diptera	4	12.9	0	0.0	2	4.5	2	5.7
Isoptera	0	0.0	0	0.0	0	0.0	1	2.9

743

744

745 **Table S2** Interseasonal differences in diet composition of the two studied toad species in West
 746 African cities. Numbers indicate the number of stomachs containing a given prey item.

	Port Harcourt (<i>S. maculata</i>)		Cotonou (<i>S. regularis</i>)		Ikeja (sympatric)		Lomé (<i>S. regularis</i>)		TOTAL	
	wet	dry	wet	dry	wet	dry	wet	dry	wet	dry
Oligochaeta	10	1	9	3	2	0	11	3	32	7
Gastropoda	0	0	0	1	5	0	7	0	12	1
Isopoda	0	0	0	0	1	0	0	0	1	0
Araneidae	6	7	3	2	0	1	0	0	9	10
Chilopoda	0	0	0	0	0	0	0	1	0	1
Coleoptera adults	8	3	4	3	2	0	2	1	16	7
Coleoptera larvae	6	8	3	4	0	0	0	0	9	12
Lepidoptera adults	0	0	0	1	0	0	1	0	1	1
Lepidoptera larvae	1	4	1	0	0	0	1	4	3	8
Vespoidea	1	2	1	0	0	1	2	0	4	3
Apoidea	1	1	2	0	0	1	0	0	3	2
Formicoidea	1	6	2	4	8	13	1	4	12	27
Blattodea	5	3	1	2	0	2	0	0	6	7
Mantoidea	0	0	0	0	1	0	0	0	1	0
Diptera	1	3	2	2	0	0	0	0	3	5
Isoptera	0	0	0	0	0	0	1	0	1	0

747

748

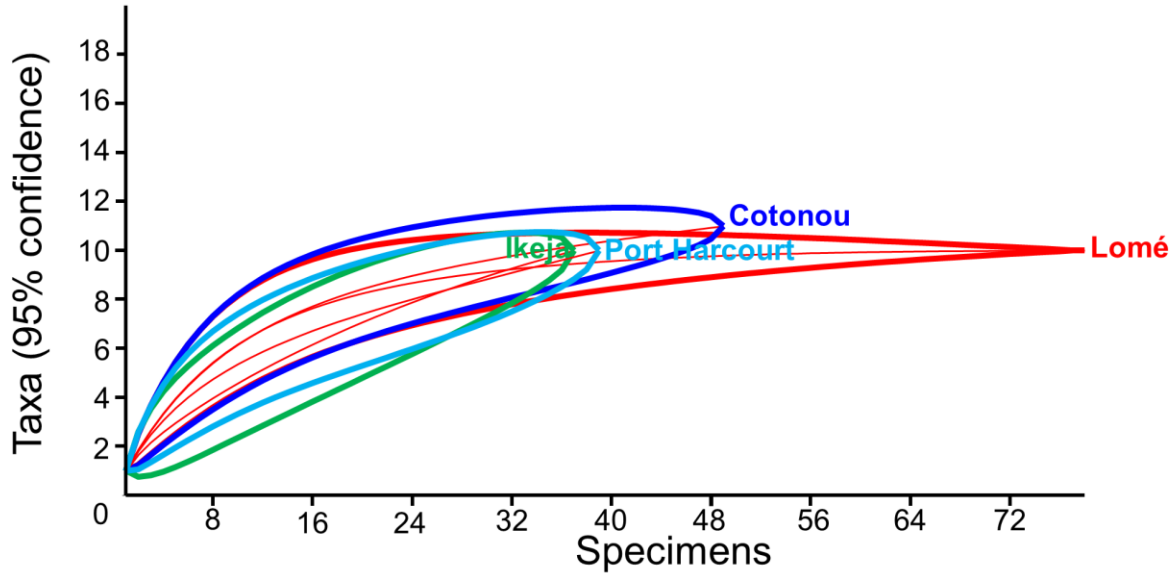
749 **Table S3** Prey availability by season and by study city.

	Port Harcourt				Cotonou			
	Wet season		Dry season		Wet season		Dry season	
	No.	%	No.	%	No.	%	No.	%
Oligochaeta	19	0.5	0	0	16	0.9	3	0.2
Gastropoda	4	0.1	0	0	11	0.6	1	0.1
Collembola	631	17.5	731	22.0	491	28.4	517	32
Isopoda	8	0.2	91	2.7	2	0.1	0	0.0
Araneidae	116	3.2	119	3.6	2	0.1	0	0.0
Chilopoda	2	0.1	0	0.0	46	2.7	7	0.4
Orthoptera	213	5.9	71	2.1	0	0.0	2	0.1
Coleoptera adults	311	8.6	107	3.2	48	2.8	22	1.4
Coleoptera larvae	8	0.2	2	0.1	13	0.8	3	0.2
Lepidoptera adults	6	0.2	1	0.0	3	0.2	2	0.1
Lepidoptera larvae	21	0.6	6	0.2	7	0.4	1	0.1
Vespoidea	31	0.9	3	0.1	6	0.3	1	0.1
Apoidea	0	0.0	0	0.0	0	0.0	0	0.0
Formicoidea	198	5.5	841	25.3	166	9.6	312	19.4
Blattodea	3	0.1	24	0.7	9	0.5	8	0.5
Mantoidea	1	0.0	0	0.0	1	0.1	0	0.0
Diptera	1435	39.7	883	26.6	447	25.9	416	25.8
Isoptera	11	0.3	0	0.0	0	0.0	0	0.0
Thysanoptera	258	7.1	116	3.5	211	12.2	134	8.3
Hemiptera	138	3.8	147	4.4	133	7.7	122	7.6
Homoptera	202	5.6	181	5.4	118	6.8	63	3.9
TOTAL	3616	100	3323	100	1729	100	1610	100

750

751

752 **Figure S1** Rarefaction curves with 95% confidence intervals generated after 9999 bootstraps for
753 prey category discoveries in relationship to sample size (b) in stomachs of *Sclerophrys regularis*
754 and *S. maculata* for four urban study areas in West Africa.



755

756