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## **Spatial and temporal structure of the fish assemblage in Akanda National Park (Gabon), an equatorial mangrove estuary**

Jean Hervé Mve Beh, Oumar Sadio, Jean Daniel Mbega, Ghislain Tchinga, Flore Tsinga, Christophe Leboulanger, Frida Ben Rais Lasram, Luis Tito de Morais, François Le Loc'h

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HAL Authorization

1 **Spatial and temporal structure of the fish assemblage in Akanda National**  
2 **Park (Gabon), an equatorial mangrove estuary**  
3

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26 Regional Studies in Marine Science

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## Abstract

30 Marine spatial planning and management processes are important tools for environmental and  
31 resource management, providing effective frameworks for considering environmental, social,  
32 cultural, institutional and economic variables within a common biogeographic context. The  
33 Akanda National Park (ANP) in Gabon, almost exclusively constituted by mangroves, is part  
34 of a green belt of protected areas around the capital city of Libreville. The creation of the ANP  
35 is considered as an essential tool for the ecosystemic management of fisheries in Mondah Bay,  
36 playing nursery function for several exploited fish species. However, this role has never been  
37 documented in the mangroves of Gabon. The aim of this study is to describe the spatial and  
38 seasonal variability of fish assemblages, to assess ANP mangrove role as a nursery for fish  
39 juveniles. Fish sampling was carried out at four different sites in the four hydroclimatic seasons  
40 in Gabon using trammel gillnets with different mesh size (10, 27 and 40 mm). Fifty-nine fish  
41 species mainly estuarine and marine, first and second level predators were collected whatever  
42 the season and the site. The numerically dominant species were *Pseudotolithus elongatus*,  
43 *Pellonula leonensis* and *Parachelon grandisquamis* (48% of the total number of individuals),  
44 whereas *P. elongatus*, *Chrysichthys nigrodigitatus* and *Plectorhinchus macrolepis* represented  
45 the main biomasses (55%). The predominance in the catches of immature individuals of many  
46 species of commercial interest and in particular, *P. elongatus*, *P. grandisquamis*, *C.*  
47 *nigrodigitatus*, *Eucinostomus melanopterus*, *Neochelon falcipinnis* and *Polydactylus*  
48 *quadrifilis*, which dominate the community, highlights the importance of Akanda mangrove as  
49 a nursery for the juveniles of these species. The results of our study are a first step in  
50 understanding the fish communities of a Gabon marine protected area, which can support the  
51 decision making management plans, zonation and initiate a monitoring program for the  
52 estuarine and marine protected ecosystems.

53 **Keywords:** Diversity, Communities, Mangroves, Conservation, Nursery, Fisheries.

54 **Introduction**

55

56 Mangroves are one of the most productive coastal tropical and subtropical forest ecosystems in  
57 the world (Costanza et al. 1997; MEA 2005; UNEP 2014). Together with their associated  
58 biodiversity, mangroves provide important ecosystem services that play a crucial role in the  
59 well-being of coastal human communities through climate regulation, food security, and  
60 poverty reduction (Baba et al. 2013; Benzeev et al. 2017; Carrasquilla-Henao and Juanes  
61 2017). Among the ecosystem services associated with mangroves, ensuring the renewal of  
62 commercial fish species stocks through nursery function is of primary importance (Beck et al.  
63 2001; Litvin et al. 2018; Carrasquilla-Henao et al. 2019). However, if in some regions of the  
64 world, this function is well documented (Nagelkerken et al. 2008; Kimirei et al. 2013), it has  
65 been scarcely addressed in Africa (France and Serafy, 2006), which hosts about 19% of the  
66 world's mangrove area (Alongi 2014; Thomas et al. 2017; Worthington and Spalding 2018).

67 Despite the lack of information on the nursery function, protected areas including mangroves  
68 are regularly created in Africa and used as strategic tools to preserve the renewal of fish stocks  
69 (Sheridan and Hays 2003; Kimirei et al. 2013; Litvin et al. 2018). The sustainability of the  
70 fisheries sector is highly relevant in Africa since this continent provides nearly 10% (10.5 MT)  
71 of the world's fisheries production (FAO 2020). However, the fisheries production is locally  
72 expected to decrease significantly (e.g. Gulf of Guinea) by 2050 as a consequence of climate  
73 change (Cheung et al. 2016). The productivity of Gabon coastal water is among the highest in  
74 the Gulf of Guinea, driven by the general equatorial dynamics and the input of large amounts  
75 of dissolved and particulate organic matter from Ogooué River (Nieto and Melin 2017). In the  
76 south of the Gulf of Guinea, the Akanda National Park (ANP), essentially constituted by  
77 mangroves, is one of the emblematic protected areas, showcase of the conservation policy of  
78 Gabon. ANP borders the country's largest agglomeration, Libreville, whose population density  
79 reaches nearly 3700 inhabitants.km<sup>-2</sup> (Moumaneix and Nkombe 2017; Pottier et al. 2017). This

80 large city adversely impacts the ANP aquatic ecosystem through discharge of domestic and  
81 industrial waste (Leboulanger et al. 2021).

82 Despite evidence of the effectiveness of national parks in Gabon, conservation objectives  
83 generate conflicts with artisanal fisheries (Ona Ona 2019). Indeed, the fishing sector is of  
84 particular importance for the country with regard to the high national consumption rate (40  
85 kg/person/year, FAO, 2020) of fishery products. This sector is especially essential, contributing  
86 to human coastal communities livelihoods through the income generated, the provision of  
87 animal proteins and the reduction of unemployment (Egombengani 2011; Cardiec, 2021).  
88 Therefore, studying the ichthyofauna of ANP is of primary importance in order to allow  
89 sustainable management of these exploited marine resources. Despite its creation in 2002, no  
90 fish assemblage inventories or assessments in ANP have been conducted to date.

91 In order to alleviate to the lack of ecological baseline studies for this area, our study aims to  
92 describe the spatial and seasonal variability of fish assemblages in the mangrove of Akanda  
93 National Park in order to understand fish community structure and dynamics and to assess its  
94 role as a nursery for juveniles of exploited fish. This knowledge will also usefully contribute to  
95 the definition of the functioning of a coastal mangrove ecosystem in Central Africa, and to new  
96 comparisons with other mangrove ecosystems, particularly in the context of global change.

97 **Materials and methods**

98 **II.1. Study zone**

99 Gabon's coastal waters are among the most productive in the Gulf of Guinea, as a result of  
100 seasonal upwelling and the input of large quantities of dissolved and particulate organic matter  
101 from the Congo and the Ogooué Rivers (Voituriez and Herbland 1982, Le Loeuff and von  
102 Cosel 1998). Nutrient rich waters support productive food webs and abundant fisheries  
103 resources that are essential for coastal populations (McGlade et al. 2002). Akanda National  
104 Park (ANP) covers an area of approximately 53,780 hectares between the Libreville peninsula  
105 and Equatorial Guinea, some 10 to 15 km northeast and east of Libreville. It is located between  
106 0°35' and 0°40' North longitude and between 9°26' and 9°33' East latitude (Van De Weghe  
107 2005). ANP is part of Mondah Bay located in the southern part of Corisco Bay (Fig. 1). The  
108 whole area belongs to the estuarine system northwest of the Gabonese coast in the geographical  
109 region of the central Gulf of Guinea. Semi-enclosed Mondah Bay is a patchwork of different  
110 habitats including large mudflats and mangroves, seagrass beds, and important areas of  
111 underwater bedrock (Lebigre and Marius 1984; Van de Weghe 2005). In Akanda, mangroves  
112 cover the vast majority of the surface of the coastal banks, nevertheless, some intertidal mud  
113 banks may also act as nursery area.

114 The ANP climate is equatorial in transition type characterized by four seasons including a long  
115 rainy season (LRS) from April to June, a long dry season (LDS) from July to September, a  
116 short rainy season (SRS) from October to December and a short dry season (SDS) from  
117 January to March. Inter-annual rainfall, vary between 2000 and 3800 mm, the number of rainy  
118 days ranges between 170 and 200 per year. The average annual temperature varies from 25 to  
119 26°C. The bay is protected from trade winds and swell by the Cap Esterias peninsula (Clist  
120 1995; Van de Weghe 2005). Akanda is subject to a microtidal regime as the maximum tidal  
121 range is about 2 m. Hydrologically, Mondah Bay is of a marine nature due to the small amount  
122 of fresh water received from its tributaries, the average of all flows being estimated at between

123 70 and 80 m<sup>3</sup>.s<sup>-1</sup>. The bathymetry of Mondah Bay results in two distinct areas: the offshore area  
124 where the waters are clear and warm and depths ranging from 1 to 21 m, with abundant benthic  
125 rocky habitats and sand beds; and the coastal area, strongly influenced by the presence of large  
126 mudflats and where bathymetry does not exceed 10 m with very turbid waters. The surface  
127 water temperature is relatively high in the range of 25-30°C (Lebigre and Marius 1984). The  
128 dominant mangrove tree species in ANP are *Avicennia nitida*, *Rhizophora harrisonii* and  
129 *Rhizophora racemosa* (Lebigre 1983; 1990). Recognized as an internationally important site  
130 for birds and marine turtles, Akanda National Park has been designated a Ramsar site since  
131 2007.

132

## 133 **II.2. Sampling strategy**

134 Based on their distance to Libreville, their relative distance from each other and their spatial  
135 coverage of the study area, four sampling sites located within the mangroves have been  
136 selected: Moka, Massotié, Babilone and Bambouchine (Fig 1). Within each site, three  
137 representative stations have been seasonally sampled (May 2017 (LRS), September 2017  
138 (LDS), November 2017 (SRS) and March 2018 (SDS)).

139 Ichthyofauna was collected with 15 m long and 1.10 m high trammel gillnets. Each net consists  
140 of three uneven mesh netting layers (two 100 mm large mesh outer layers and one 10, 27 or 40  
141 mm small mesh loose inner layer) made of green polyamide nylon. In order to obtain a  
142 representative sample and minimize net selectivity bias at each station, three trammel nets (10,  
143 27 and 40 mm mesh size respectively) connected to each other were deployed. In total, three  
144 lines of three trammel nets were deployed each time within the mangrove at each sampling site  
145 during each season. The nets are set at 17h00 and visited at 7h00. the next day for night  
146 fishing. They are again visited at 16h00. for daytime fishing and lifted at 7h00 the next day, i.e.  
147 a fishing effort of about 38 hours. After each fishing session, all the individuals caught were  
148 determined to the lowest possible taxonomic level using identification keys (Stiassny et al.

149 2007; Carpenter 2016; Carpenter and de Angelis 2016). All fish caught were counted and the  
150 total length (TL), standard length (SL) and total weight were measured. Temperature, pH,  
151 salinity, conductivity and dissolved oxygen have been measured in the water surface with a  
152 multiparameter HANNA Hi 9828 probe.

153

### 154 **II.3 Fish assemblages**

155 The estuarine use functional group classification proposed by Elliott et al. (2007) and refined  
156 by Potter et al. (2015) was employed to describe the composition of the fish assemblages. This  
157 classification based on fish species defines four main categories: marine, estuarine, diadromous  
158 and freshwater divided in guilds that represent characteristics associated to the locations of  
159 spawning, feeding and/or refuge utilization. Thus, the marine category gathers Marine  
160 Straggler (MS), Marine Estuarine-Opportunist (MMO) and Marine Estuarine-Dependent  
161 (MMD), the estuarine category is divided in Estuarine Resident (ER) and Estuarine Migrant  
162 (EM), the diadromous category regroups Anadromous (AN), Semi-Anadromous (SA),  
163 Catadromous (CA), Semi-Catadromous (SC) and Amphidromous (AM), the freshwater  
164 category composed of Freshwater Migrant (FM) and Freshwater Straggler (FS). In order to  
165 estimate the occupation of the mangroves of Akanda National Park by exploited species,  
166 sampled fishes were classified into three categories of high (HCV), medium (MCV) and no  
167 commercial value (NCV) according to local market criteria.

168

### 169 **II.4. data analysis**

170 As a preliminary analysis of the fish assemblages, species richness (S), Shannon (H') and  
171 Pielou (J) diversity indexes, abundance and biomass were examined by sampling station and  
172 season.

173 The Shannon index (H') was calculated according to the following formula (Pielou 1969):

174 
$$H' = \sum_{i=1}^S p_i \times \log_2 p_i$$

175 Where S is the species richness, i is a species, p<sub>i</sub> is the proportion of a species i to the total  
176 number of species.

177 The evenness rate (J) of Pielou, which can range from 0 to 1 was calculated as:

178 
$$J = \frac{H'}{H'_{\max}}$$

179 Where H' max = ln S

180 To estimate the species richness in the mangrove area of the ANP, the Chao-2 and Boot  
181 indices, the Jackknife 1 and 2 indices were calculated using the “vegan” R package (Gotelli  
182 and Colwell 2010).

183 To assess the proportion of juveniles in the fish populations, we assumed that fish smaller than  
184 the L<sub>50</sub> were juveniles. The L<sub>50</sub> represents the size at which 50% of the individuals in a  
185 population are mature and were obtained from the extant scientific literature (Table 4).

186 When the criteria of normality and homogeneity of variances were met, a one-way ANOVA  
187 was performed to compare each diversity indicator (S, H', J) between the 4 seasons and the 4  
188 sites. Due to the non-respect of the normality and/or homogeneity of variances of the  
189 abundance, biomass and environmental factors, the non-parametric Kruskal-Wallis test was  
190 used to compare the parameters between seasons and sites. For abundance and biomass, the  
191 data were transformed into Log(x+1) in order to stabilize the variances that were too high  
192 between fishing haul. A Factorial Correspondence Analysis (FCA) was performed to explore  
193 spatio-temporal patterns of the fish assemblages. Statistical processing and graphics were made  
194 using the “vegan” library for R software (R Core Team, 2022).

## 195 **Results**

### 196 **III.1. Environmental characteristics**

197 No significant difference for salinity, temperature and dissolved oxygen concentration  
198 (expressed as % of saturation) was found between seasons all stations combined (Appendix 1).  
199 During the whole sampling survey, salinity ranged from 1.2 in Long Rainy Season in Massotié  
200 to 30.5 in Long Dry Season in Moka (Figure 2; Appendix 1). The average salinity was  
201 significantly different between sites (Kruskal-Wallis, p-value = 0.029) and lower in Massotié  
202 than in the 3 other sampling stations. Water temperature ranged from 20.1°C in Babilone in  
203 Short Rainy Season to 31.6°C in Bambouchine in SRS. The average temperature was also  
204 significantly different between sites (Kruskal-Wallis, p-value = 0.029) and lower in Babilone.  
205 Dissolved oxygen ranged from 11.0% of saturation in Large Rainy Season in Bambouchine to  
206 85.7% in Short Dry Season in Massotié. The average dissolved oxygen percentage was  
207 significantly different between sites (Kruskal-Wallis, p-value = 0.00614) (Appendix 1),  
208 Massotié having the highest values.

209

### 210 **III.2. Description of fish assemblage**

#### 211 **Synthetic descriptors: species richness, abundance, biomass**

212 Overall, 1580 individuals belonging to 59 species and 29 families representing a total biomass  
213 of 150.17 kg were collected (Table 2). Mugilidae (19.7%) and Sciaenidae (19.4%) were the  
214 dominant families in terms of abundance while Sciaenidae and Claroteidae (25.2 and 20.2%  
215 respectively) were the main contributors to total biomass. Three species represented 48% of the  
216 total number of fishes inventoried: *Pseudotolithus elongatus* (18%), *Pellonula leonensis* (15%)  
217 and *Parachelon grandisquamis* (15%). In terms of biomass, three species dominated the  
218 assemblage: *P. elongatus* (24%), *Chrysichthys nigrodigitatus* (21%) and *Plectorhinchus*  
219 *macrolepis* (11%). Sciaenidae together with Claroteidae in Massotié (60%) and together with  
220 Haemulidae in Moka (59%) dominated the biomass. In Bambouchine, Claroteidae and

221 Dasyatidae represented 58% of the biomass of the assemblage while in Babilone, Gerreidae,  
222 Dasyatidae, and Haemulidae were the main contributor of the fish biomass (60%).  
223 *P. grandisquamis* (88% of occurrence), *Ilisha africana* (81% of occurrence), *Polydactylus*  
224 *quadrifilis* and *Monodactylus sebae* (75% of occurrence), *P. elongatus* (69% of occurrence), *C.*  
225 *nigrodigitatus* (63% of occurrence) were the most common species in the ANP. *I. africana*, *M.*  
226 *sebae* and *Eucinostomus melanopterus* were the most abundant in Babilone (51% of the  
227 abundance), *P. leonensis* and *E. melanopterus* in Bambouchine (48% of the abundance), *P.*  
228 *elongatus*, *P. grandisquamis* and *P. leonensis* (70% of the abundance) and *P. elongatus*, *I.*  
229 *africana* and *Neochelon falcipinnis* in Moka (60% of the abundance).  
230 The species richness (S) varied according to season from 29 during the LDS and SDS to 37  
231 during the LRS, and according to sampling station from 26 in Babilone to 36 species in  
232 Massotié (Table 3). While, the overall fish species richness caught in the ANP is 59, the Boot  
233 and Chao-2 indices predicted  $67\pm 4$  and  $88\pm 18$  species respectively, and the Jackknife 1 and  
234 Jackknife 2 indices predicted  $79\pm 7$  and  $91\pm 5$  species respectively. The Shannon and Pielou  
235 indexes were not significantly different between seasons and between sites (Kruskal-Wallis, p-  
236 value > 0.05; Table 3). No significant differences (Kruskal-Wallis, p-value > 0.05) were found  
237 for fish abundance and biomass between seasons or between sampling sites (Table 3).

### 238 **Structure of the assemblages**

239 The fish assemblage in Akanda National Park is dominated in terms of species richness by 39  
240 marine species (MS, MMO, MMD) accounting for 66% of the total diversity, while estuarine  
241 and freshwater fishes species represent 17% (10 species) and 14% (8 species) of the species  
242 richness respectively (Table 2). The mean abundances were not significantly different within  
243 the 4 seasons (Kruskal-Wallis, p-value = 0.7963) and ranged from 65 individuals in LDS to  
244 168 individuals in LRS (Fig. 3a). Species from marine origin dominated in all seasons from 45  
245 in LDS to 53% in SRS (Fig. 3b). As for seasons, the mean abundance was not significantly  
246 different between sites (Kruskal-Wallis, p-value = 0.2859) and ranged from 37.7 in Babilone to

247 159.2 individuals in Massotié (Fig. 3c). Species from marine origin (MS, MMO and MME)  
248 were the most represented in Moka (64% of the abundance), Babilone (75%) and Bambouchine  
249 (49%), (Fig. 3d).

250 The mean fish biomass was not significantly different between seasons (Kruskal-Wallis, p-  
251 value = 0.1455) nor between sampling stations (Kruskal-Wallis, p-value = 0.3032).

252 The factorial correspondence analysis carried out on the faunal table produced a first factorial  
253 design explaining 26.4% of the total inertia (14.4% for axis 1 and 12% for axis 2) (Fig. 5a).

254 Projection of the seasons onto the first factorial plan reveals an opposition between the long  
255 dry season group and the ones formed by the long rainy season, the short rainy season and the  
256 short dry season (Fig. 5c). The projection separates the 4 sampling sites on the basis of low  
257 occurrence species (Fig. 5d). The projection of ecological (Fig. 5e) did not indicate opposition  
258 on the first two axes. However, during the long dry season, Bambouchine was differentiated by  
259 the presence of freshwater stragglers.

## 260 **Exploited species**

261 The classification of the collected fish species revealed 31 species with high commercial value,  
262 10 of medium commercial value and 18 with no commercial value. The individual sizes (TL)  
263 of fish caught in the ANP varied from 4.8 cm (*Monodactylus sebae*) to 110.2 cm (*Fontitrygon*  
264 *margarita*). However, the size spectrum of the species with high commercial value and for  
265 which more than 50 individuals were collected (6 species: 53% of the individuals) (Fig. 6) is  
266 uni-modal with a mode ranging from 7 to 12 cm accounting for 46% of the individuals. For  
267 these 6 species, the proportion of individuals below the L<sub>50</sub> varied from 21.8% (*Chrysichthys*  
268 *nigrodigitatus*) to 100% (*Polydactylus quadrifilis*) (Table 4). The estuarine species from  
269 marine origin and marine estuarine species (*Eucinostomus melanopterus*, *Neochelon*  
270 *falcipinnis*, *Parachelon grandisquamis*, *Polydactylus quadrifilis*, *Pseudotolithus elongatus*) had  
271 more than 80% of their population below L<sub>50</sub>.

272

273 **Discussion**

274 In the marine realm, biodiversity and associated ecosystem services are threatened by  
275 numerous anthropogenic stressors, such as overfishing, pollution, climate change and  
276 biological invasions (IPBES 2019). In this context, Marine Protected Areas (MPAs) and  
277 Estuarine Protected Areas (EPAs) are promoted as tools to help conserve biodiversity heritage,  
278 maintain ecosystem processes, and favor a sustainable exploitation of living resources (Wood  
279 et al., 2008; Whitfield et al, 2020).

280 MPAs are currently among the main promoted strategies to mitigate the rapid loss of marine  
281 biodiversity and ecosystem services. While scientists recognize the benefits of MPAs (e.g.  
282 biomass increases, spillover, and larval export), only a very small percentage of the ocean is  
283 protected by MPAs worldwide (Wood et al. 2008, Grorud-Colvert et al. 2021). The protection  
284 of estuarine areas which are necessary ecosystems for the completion of life cycles of many  
285 fishes is complementary to MPAs.

286 The establishment of an efficient Estuarine or Marine Protected Area network requires the  
287 validation of three conditions, namely (i) representativeness (all species are represented in the  
288 conservation network), (ii) persistence (once established, the conservation network should  
289 promote the maintenance of natural processes by excluding all threats) and (iii)  
290 complementarity (the selected spatial units do not must be neither similar nor redundant)  
291 (Margules and Pressey 2000).

292 To reach these conditions, Systematic Conservation Planning (SCP) is a widely-used approach  
293 to develop efficient networks of protected areas (Margules and Pressey 2000). While huge  
294 methodological improvements have been done these last years in SCP that is increasingly  
295 being used in both marine and terrestrial ecosystems (Weeks and Jupiter 2013; Alvarez  
296 Romero et al. 2018; Chamberlain et al. 2022), there are still poor diversity data areas  
297 remaining, particularly in African coastal and estuarine ecosystems, to ensure the  
298 representativeness of basic condition.

299 Species assemblage's description is thus a prerequisite step towards more advanced EPA and  
300 MPA planning techniques. This is even more important in African mangroves areas where very  
301 little is known about fish assemblages that ensure biomass provision for fisheries (Blaber  
302 2013). By giving insight into spatial and temporal structure of fish assemblages in the  
303 mangrove ecosystem of the Akanda National Park estuary in Gabon, this study provides a  
304 valuable data for a future efficient management.

305

### 306 *Environmental parameters*

307 The study of factors affecting the spatial distribution of species is a central issue in ecology  
308 (Wiens 1989). Understanding the determinants of the spatial distribution of species in  
309 mangroves is difficult because of the complex and dynamic nature of these ecosystems. This  
310 ecosystem complexity is due to multiple factors affecting species-habitat associations,  
311 difficulty in sampling, variation in the scales at which determinants operate and high variability  
312 of environmental parameters due to river inputs (Johnson et al. 2013).

313 In the mangrove area of Akanda National Park, the environmental parameters (temperature,  
314 salinity and dissolved oxygen) were stable across seasons. Environmental spatial variations  
315 were more significant within the ANP reflecting local variabilities within a season. Indeed,  
316 salinity was lower in Massotié and higher in Moka, whereas water masses were warmer in  
317 Bambouchine and more oxygenated in Massotié. As a whole, ANP mangrove waters were  
318 depleted in dissolved oxygen relative to atmospheric saturation, resulting in a moderate  
319 hypoxia during most of the survey. Dissolved oxygen levels could partly modulate fish  
320 migration in mangroves (Dubuc et al. 2019) and temporally regulate diversity and abundance  
321 of fish species. These measurements are consistent with those of Lebigre and Marius (1986)  
322 and Leboulanger et al. (2021) who reported homogeneity of salinity in the western part of the  
323 bay including Moka station. Indeed, the rivers in this area dry up for the most part during the  
324 dry seasons combined with the greater influence of the Atlantic Ocean in this area lead to the

325 highest salinity values. Besides, in the eastern part of the bay, the salinity is much lower due to  
326 the strong inflow of fresh water from small rivers, including Massotié.

327

### 328 ***Fish species richness***

329 In this study, we identified 59 species of fish belonging to 29 families in the mangroves area of  
330 the Akanda National Park. Based on our sampling, species richness estimators assess the  
331 number of fish species in the range of 67 to 91 for the ANP (i.e., 13 to 54% more species than  
332 sampled). An ideal species richness estimator would be unbiased (it neither overestimates nor  
333 underestimates species richness), precise, and efficient (Gotelli and Colwell, 2010).  
334 Nevertheless, the species richness registered and assessed in our study underestimate the fish  
335 species richness reported in the area based on a bibliographic synthesis of grey literature (105  
336 fish species identified in the ANP). More, our study identified 10 additional fish species not  
337 previously inventoried in the area, which brings the total fish species richness to 115 in the area  
338 (Appendix 3). Among the 56 fish species already recorded in Akanda but not present in our  
339 study, 28 were recorded only once and 9 only twice out of the 8 studies synthesized and can be  
340 considered as rare. The 19 other species are mostly pelagic species (e.g. *Alectis alexandrina*,  
341 *Platybelone argalus*, *Megalops atlanticus*) or freshwater (*Pelmatolapia cabrae*, *Sarotherodon*  
342 *nigripinnis*, *Kribia kribensis*) or marine species (*Orcynopsis unicolor*, *Sphyrnaena guachancho*)  
343 that are difficult to capture with our sampling strategy (Appendix 3).

344 As the diversity of fish within the estuaries of Gabon and more generally of Central Africa is  
345 poorly documented, our study is of particular importance in benchmarking fish species  
346 diversity and richness in the region. At the scale of Gabon the fish species richness is high,  
347 1,062 valid species of fishes are registered in Gabonese waters, with 288 of these strictly  
348 restricted to freshwaters, 592 strictly restricted to marine environments and 182 species  
349 euryhaline species (Fermon et al. 2022). At a local scale, compared to other coastal system of  
350 the Gulf of Guinea, the ANP fish species richness is higher than in Sao Tomé island mangroves

351 (20 species, Felix et al. 2017, Cravo et al, 2021), Lake Nokoué (51 species, Benin, Lalèyè et al.  
352 2003), Ogooué estuary (66 species, Gabon, Loubens 1966), Fatala estuary (102 species,  
353 Guinea, Baran 1995), Saloum estuary (114 species, Senegal, Diouf 1996) or Lagos lagoon (115  
354 species, Nigeria, Oribhador and Ezenwa 2005) but lower than in Ebrié lagoon (153 species,  
355 Ivory Coast, Albaret 1994). At a more global scale, mangrove fish diversity is higher in Indo-  
356 West Pacific mangroves as in Embley (197 species, Australia, Blaber et al. 1989) or Vellar  
357 Coleroon (195 species, India Krishnamurthy and Jeyaseelam, 1981) than in Gabonese  
358 mangrove and at the level of those of West Atlantic as in Ciénaga Grande (114 species,  
359 Colombia, Leon and Racedo, 1985) and East Pacific as in Guerrero Lakes (105 species,  
360 Mexico, Yáñez-Arancibia, 1978). Biogeography (i.e. geographical location) and connectivity  
361 (Blaber, 2013) play an important role in species richness patterns. Tropical and subtropical  
362 estuaries have a higher species richness than temperate systems, mainly due to the greater  
363 richness of fauna associated with habitats closer to the equator, whether marine or riverine  
364 (Whitfield 2005). Other factors, often interdependent, can explain species distribution: the  
365 physico-chemical characteristics of the water and their spatio-temporal variations (Albaret  
366 1999; Sosa-Lopez et al. 2007), the trophic richness and the availability of resources (Whitfield  
367 1988), the presence, extent and state (health) of the mangrove (FAO 2007).

368

### 369 *Fish assemblage*

370 In ANP, fish species richness was close between the four seasons and between the four sites.  
371 The fish assemblage in the mangrove area of ANP was characterized by rare occurrence of  
372 freshwater species, and the abundance of species of marine origin (marine stragglers and  
373 marine migrants). Marine species represented more than 60% of the overall species richness  
374 and from 32% (Massotié) to 74% (Babilone) of the total abundance per site and more than 45%  
375 per season. This community composition, dominated by marine species, confirms the marine  
376 character of the ANP, which results from its strong link with the marine environment, coupled

377 with the low input of freshwater from the watersheds. Freshwater species were confined to the  
378 oligohaline portions as in Massotié.

379 *Parachelon grandisquamis*, *Ilisha africana*, *Monodactylus sebae* and *Polydactylus quadrifilis*  
380 were the most common species (occurrence>80%). These four species associated with the two  
381 most abundant species *Pseudotolithus elongatus* and *Pellonula leonensis* constituted the base  
382 of the ANP species assemblage. This assemblage is similar to the one described by Loubens  
383 (1966) in the mangroves of the Ogooué estuary (Gabon) and by Ecoutin et al. (2005) in the  
384 marine-influenced part of the Ebrié lagoon (Côte d'Ivoire). The ANP fish assemblage is  
385 directly related to the Scianidae estuary and coastal community assemblage described by  
386 Longhurst (1965) in Sierra Leone and the coastal settlement described by Durand (1967) in  
387 Congo and is typical of all desalinated coastal areas of Western Central Africa. *Pseudotolithus*  
388 *elongatus*, *Polydactylus quadrifilis* as well as the Mugilidae species are among the most caught  
389 species both around the ANP (Mve Beh et al. 2017) and at national level (Belhabib 2015).

390

### 391 ***Nursery role***

392 Among the most abundant fish in the ANP, *Eucinostomus melanopterus*, *Neochelon*  
393 *falcipinnis*, *Parachelon grandisquamis*, *Polydactylus quadrifilis* and *Pseudotolithus elongatus*  
394 were predominantly caught at sizes below sexual maturity. Habitats that host a higher  
395 percentage of juveniles are defined as having high nursery value (Beck et al. 2001), confirming  
396 the ANP status of a habitat for the juveniles of these exploited fishes. Mangroves are known to  
397 benefit coastal resources by supporting the early stages of commercial and non-commercial  
398 fauna as fish (Tomlinson 2016). The nursery role of mangroves is mainly due to structural  
399 complexity and is driven by the structural uniqueness of mangrove microhabitats (Vorsatz et al.  
400 2021) that provide shelter and protection against predators and availability of food  
401 (Laegdsgaard and Johnson 2001). Thus, juvenile fish benefit from these conditions in ANP that  
402 provide a favorable and safe environment for their development. However, our study did not

403 cover first juvenile fishes settlement in the mangroves. In order to fully understand the role of  
404 the mangroves to various fish species, the study of the smallest sizes among fish assemblage  
405 requires a dedicated study, using appropriate sampling equipment.

406

#### 407 **Conclusion**

408 Based on a systematic approach to conservation planning designed to achieve biodiversity  
409 goals while minimizing impacts on ocean resource users, Gabon created in 2017 a network of  
410 MPAs aiming at protecting 26% of the Exclusive Economic Zone, and have committed to  
411 protect 30% of their waters by 2030 (Metcalf et al 2021). Nevertheless, filling in the gaps of  
412 scientific knowledge related to data-poor areas in order to support MPA management such as  
413 in Gabon and low-income countries is a great challenge (Metcalf et al. 2021). The results of  
414 this study are a first step in understanding the fish communities of Akanda National Park,  
415 which can complement the management plan and initiate a monitoring program for the park  
416 taking into account the customary management by local communities and indigenous and local  
417 knowledge (ILK) which is increasingly recognized as an essential tool in ecosystem  
418 management (Loch and Riechers 2021). This study demonstrated the nursery role of the ANP  
419 for exploited species and the need to preserve it to maintain sustainable fisheries. Nevertheless,  
420 the importance of mangroves for all 0+ juveniles should be emphasized, and targeted studies to  
421 fill this research gap should be a priority. Moreover, the number of species recorded for this  
422 area may still be underestimated. The use of appropriate complementary methods to detect  
423 cryptic species (e.g., eDNA and non invasive observation systems) and long-term qualitative  
424 studies should allow for greater precision in defining and monitoring fish assemblages,  
425 especially in the context of climate change and urban constraints, including pollution, related to  
426 the vicinity of Libreville, which have a direct impact on conservation objectives. In addition,  
427 studies on other biological groups, such as benthic and pelagic invertebrates combined with  
428 trophic modeling, would provide a better understanding of the trophic functioning of the park.

429

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436 **References**

- 437
- 438 Ajagbe, S.O., Odulate, D.O., Ajagbe, R.O., Ariwoola, O.S., Abdulazeez, F.I., Oyewole, O.O.,
- 439 M.T. Ojubolamo, I.O., Arabambi, I.E. Odiaka, B.O. Fadimu, A.O. Olomola, O.A. Ganiyu,
- 440 yekan, O.O. 2021. Population dynamics of *Chrysichthys nigrodigitatus* (Lacépède, 1803)
- 441 in Ikere-gorge, Oyo State, Nigeria. *Ghana Journal of Agricultural Science* 56(1): 79-86.
- 442 Albaret, J.-J., 1994. Les poissons: biologie et peuplements. In: Durand J.-R., Dufour P. , Guiral
- 443 D. , Zabi S.G.F. (eds.) Environnement et ressources aquatiques en Côte d'Ivoire: 2. Les
- 444 milieux lagunaires, Paris: ORSTOM, p. 239-280
- 445 Albaret, J.-J., 1999. Les peuplements des estuaires et des lagunes. In: Lévêque, C. & Paugy, D.
- 446 (eds.) Les poissons des eaux continentales africaines. Paris: IRD, 325-349.
- 447 Alongi, M. 2014. Present state and future of the world's mangrove forests present state and
- 448 future of the world's mangrove forests. *Environmental Conservation* 29(3): 20.
- 449 <https://doi.org/10.1017/S0376892902000231>.
- 450 Álvarez-Romero, J.G., Mills, M., Adams, V.M., Gurney, G.G., Pressey, R.L., Weeks, R., Ban,
- 451 N.C., Cheok, J., Davies, T.E., Day, J.C., Hamel, M.A., Leslie, H.M., Magris, R.A.,
- 452 Storlie, C.J. 2018. Research advances and gaps in marine planning: towards a global
- 453 database in systematic conservation planning. *Biological Conservation* 227: 369–382.
- 454 <https://doi:10.1016/j.biocon.2018.06.027>.
- 455 Baba, S., Chan, H.T., Aksornkoe, S. 2013. Useful products from mangrove and other coastal
- 456 plants. Edited by ISME Mangrove Educational Book Series No. 3. the International
- 457 Society for Mangrove Ecosystems (ISME), Okinawa, Japan, and the International
- 458 Tropical Timber Organization (ITTO), Yokohama, Japan.
- 459 [http://www.mangroverestoration.com/pdfs/Baba Chan and Aksornkoe educational-](http://www.mangroverestoration.com/pdfs/Baba Chan and Aksornkoe educational-series.book3.pdf)
- 460 [series.book3.pdf](http://www.mangroverestoration.com/pdfs/Baba Chan and Aksornkoe educational-series.book3.pdf).
- 461 Baran, E. 1995. Dynamique spatio-temporelle des peuplements de poissons estuariens en
- 462 Guinée: Relations avec le milieu abiotique. PhD Thesis, Université de Bretagne

463 Occidentale, Brest. 236p. [http://horizon.documentation.ird.fr/exl-doc/pleins\\_textes/pleins\\_textes\\_6/TDM/42826.pdf](http://horizon.documentation.ird.fr/exl-doc/pleins_textes/pleins_textes_6/TDM/42826.pdf)

464

465 Beck, M.W., Heck K.L, Able K.W, Childers D.L., Eggleston D.B., Gillanders B.M., Halpern  
466 B., et al. 2001. The identification, conservation, and management of estuarine and marine  
467 nurseries for fish and invertebrates. *BioScience* 51(8): 633. [https://doi.org/10.1641/0006-3568\(2001\)051\[0633:ticamo\]2.0.co;2](https://doi.org/10.1641/0006-3568(2001)051[0633:ticamo]2.0.co;2).

468

469 Belhabib, D. 2015. Gabon fisheries between 1950 and 2010: a catch reconstructing, 11. This  
470 working paper is made available by the Fisheries Centre, University of British Columbia,  
471 Vancouver, BC, V6T 1Z4, Canada.

472 Benzeev, R. Hutchinson N., Friess D.A. 2017. Quantifying fisheries ecosystem services of  
473 mangroves and tropical artificial urban shorelines. *Hydrobiologia* 803(1): 225–237.

474 Blaber, S.J.M. 2013. Fishes and fisheries in tropical estuaries: The last 10 years. *Estuarine,  
475 Coastal and Shelf Science* 135: 57-65. <https://doi.org/10.1016/j.ecss.2012.11.002>.

476 Blaber, S.J.M., Brewer D.T., Salini J.P. 1989. Species composition and biomasses of fishes in  
477 different habitats of a tropical northern Australian estuary: their occurrence in the  
478 adjoining sea and estuarine dependence. *Estuarine Coastal and Shelf Science* 29: 509–  
479 531. [https://doi.org/10.1016/0272-7714\(89\)90008-5](https://doi.org/10.1016/0272-7714(89)90008-5)

480 Cardiec, F. 2021. Pêche artisanale maritime au Gabon : fonctionnement, spatialisation et aires  
481 marines protégées. PhD Thesis. Université de Bretagne Occidentale. 231 p.  
482 <https://www.theses.fr/2021BRES0013>

483 Carpenter, K.E., de Angelis N., 2016. The living marine resources of the Eastern Central  
484 Atlantic. FAO species identification guide for fishery purposes 3(1): 1-859.

485 Carpenter, K.E. 2002. The living marine resources of the Western Central Atlantic FAO  
486 species identification guide for fishery purposes. 1: 1375–2127.  
487 <https://doi.org/10.1021/cb400140u>.

488 Carrasquilla-Henao, M., Juanes F. 2017. Mangroves enhance local fisheries catches: a global

489 meta-analysis. *Fish and Fisheries* 18(1): 79–93. <https://doi.org/10.1111/faf.12168>.

490 Carrasquilla-Henao, M., Ban, N., Rueda, M., Juanes F. 2019. The mangrove-fishery  
491 relationship: a local ecological knowledge perspective. *Marine Policy* 108: 103656.  
492 <https://doi.org/10.1016/j.marpol.2019.103656>.

493 Chamberlain, D.A., Possingham, H.P., Phinn, S.R. 2022. Decision-making with ecological  
494 process for coastal and marine planning: current literature and future directions. *Aquatic  
495 Ecology* 56(1): 1–19. <https://doi:10.1007/s10452-021-09896-9>.

496 Cheung, W.W.L., Jones, M.C., Reygondeau, G., Stock, C.A., Lam, V.W.Y., Frölicher, T.L.,  
497 2016. Structural uncertainty in projecting global fisheries catches under climate change,  
498 *Ecological Modelling* 325: 57-66. <https://doi.org/10.1016/j.ecolmodel.2015.12.018>.

499 Clist, B., 1995. Gabon, 100 000 ans d’histoire. Edited by Centre Culturel Français de  
500 Libreville, Gabon. 380 p.

501 Costanza, R., d’Arge R., de Groot R., Farber S., Grasso M., Hannon B., Limburg K., et al.  
502 1997. The value of the world’s ecosystem services and natural capital. *Nature* 387 (6630):  
503 253–60. <https://doi.org/10.1038/387253a0>.

504 Cravo, M., Almeida, A.J., Lima, H., Azevedo e Silva, J., Bandeira, S., Machava-António, V.,  
505 Paula, J. 2021. Fish assemblages in a small mangrove system on Príncipe Island, Gulf of  
506 Guinea. *Frontiers in Marine Science* 8:721692.  
507 <https://doi.org/10.3389/fmars.2021.721692>

508 Diouf, P.S. 1996. Les peuplements de poissons des milieux estuariens de l’Afrique de l’Ouest:  
509 l’exemple de l’estuaire hyperhalin du Sine-Saloum. Thèse de Doctorat 3<sup>ème</sup> Cycle,  
510 Université de Montpellier II, p. 267.  
511 [http://www.bondy.ird.fr/pleins\\_textes/pleins\\_textes\\_7/TDM\\_7/010008130.pdf](http://www.bondy.ird.fr/pleins_textes/pleins_textes_7/TDM_7/010008130.pdf)

512 Djadji, E.L.G., Sylla, S., Zan-Bi, T.T., Atse, B.C. 2018. Reproductive biology of the mullet  
513 *Liza falcipinnis* (Valenciennes, 1836) in two african complex lagoons (Ebrié and Grand-  
514 Llahou) (Côte d’Ivoire). *International Journal of Research – Granthaalayah* 6(5): 114-

515 127.

516 Dubuc, A., Baker, R., Marchand, C., Waltham, N. J., Sheaves, M. 2019. Hypoxia in  
517 mangroves: occurrence and impact on valuable tropical fish habitat. *Biogeosciences* 16:  
518 3959–3976, <https://doi.org/10.5194/bg-16-3959-2019>

519 Durand, J.-R. 1967. Etude des poissons benthiques du plateau continental congolais : troisième  
520 partie : étude de la répartition, de l'abondance et des variations saisonnières. *Cahiers*  
521 *ORSTOM Série Océanographie* 2: 3-68.

522 Ecoutin, J.-M., Richard, E., Simier, M., Albaret, J.-J. 2005. Spatial versus temporal patterns in  
523 fish assemblages of a tropical estuarine coastal lake: The Ebrié Lagoon (Ivory Coast).  
524 *Estuarine, Coastal and Shelf Science* 64(4): 623-635.  
525 <https://doi.org/10.1016/j.ecss.2005.04.002>.

526 Egombengani, L.B. 2011. Dynamique des changements dans l'activité de la pêche au Gabon de  
527 1900 à nos jours. PhD Thesis. Université Victor Segalen Bordeaux 2. 425 p.  
528 <https://www.theses.fr/2011BOR21897/document>

529 Elliott, M. Whitfield, A.K., Potter, I.C., Blaber, J.M., Cyrus, D.P., Nordlie, F.G., Harrison,  
530 T.D. 2007. The guild approach to categorizing estuarine fish assemblages: a global  
531 review. *Fish and Fisheries* 8: 241-268

532 FAO 2007. The world's mangroves 1980-2005. FAO forestry paper 153, 89. Rome: FAO.

533 FAO 2020. The state of world fisheries and aquaculture 2020. Sustainability in action. Rome.  
534 <https://doi.org/10.4060/ca9229en>

535 Faunce, C.H., Serafy, J.E. 2006. Mangroves as fish habitat : 50 years of field studies. *Marine*  
536 *Ecology Progress Series* 318: 1–18.

537 Félix, P.M., Chainho, P., Lima, R.F., Costa, J.L., Almeida, A.J., Domingos, I., Brito, A.C.  
538 2017. Mangrove fish of São Tomé Island (Gulf of Guinea): new occurrences and habitat  
539 usage. *Marine and Freshwater Research* 68(1): 123–30.  
540 <https://doi.org/10.1071/MF15392>.

541 Fermon Y., Bailly N., Cardiec F., Causse R., Chartrain E., et al. 2022. An annotated checklist  
542 of the fishes of Gabon. *Cybium* 46(2-3): 69-317. [https://doi.org/10.26028/cybium/2022-](https://doi.org/10.26028/cybium/2022-462-3-001)  
543 462-3-001

544 Gotelli, N.J., Colwell, R.K. 2010. Chapter 4: Estimating species richness. In biological  
545 diversity: frontiers in measurement and assessment. Edited by A.E. Magurran and B.J.  
546 McGill. Oxford University Press, Oxford, U.K. pp. 39–54.

547 Green, A., Smith, S., Lipsett-Moore, G., Groves, C., Peterson, N., Sheppard, S., . . . Bualia, L.  
548 (2009). Designing a resilient network of marine protected areas for Kimbe Bay, Papua  
549 New Guinea. *Oryx* 43(4): 488-498. <https://doi.org/10.1017/S0030605309990342>

550 Grorud-Colvert, K., Sullivan-Stack, J., Roberts, C., Constant, V., Horta e Costa, B. et al.,  
551 2021. The MPA Guide: A framework to achieve global goals for the ocean. *Science* 373,  
552 eabf0861

553 IPBES, 2019. Global assessment report on biodiversity and ecosystem services of the  
554 Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. E. S.  
555 Brondizio, J. Settele, S. Díaz, and H. T. Ngo (editors). IPBES secretariat, Bonn, Germany.  
556 1148 pages. <https://doi.org/10.5281/zenodo.3831673>

557 Johnson, A.F., Jenkins, S.R., Hiddink, J.G., Hinz, H. 2013. Linking temperate demersal fish  
558 species to habitat: scales, patterns and future directions. *Fish and Fisheries* 14: 256–280.

559 Kimirei, I.A., Nagelkerken, I, Mgya, Y.D., Huijbers, C.M. 2013. The mangrove nursery  
560 paradigm revisited: otolith stable isotopes support nursery-to-reef movements by Indo-  
561 Pacific fishes. *PLoS ONE* 8 (6). <https://doi.org/10.1371/journal.pone.0066320>.

562 Konan, K.S., Djadji, E.L.G., Amon, Y.N., N'da, K. 2019. Determination of the sexual maturity  
563 of Threadfins *Polydactylus quadrifilis* (Cuvier, 1829), *Galeoides decadactylus* (Bloch,  
564 1795) and *Pentanemus quinquarius* (Linné, 1758) of the artisanal marine fishery of  
565 Grand-Lahou (Ivory Coast). *Journal of Scientific Research & Reports* 23(1): 1-9.  
566 <https://doi: 10.9734/JSRR/2019/v23i130112>.

567 Krishnamurthy, K., Jeyaseelan. M.J. 1981. Early life history of fishes from Pichavaram  
568 mangrove ecosystem of India. *Rapports et Procès Verbaux des Réunions, Conseil*  
569 *Permanent International pour l'exploration de la Mer* 178: 416–423.

570 Laegdsgaard, P., Johnson, C. 2001. Why do juvenile fish utilise mangrove habitats? *Journal of*  
571 *Experimental Marine Biology and Ecology* 257 (2): 229–53.  
572 [https://doi.org/10.1016/S0022-0981\(00\)00331-2](https://doi.org/10.1016/S0022-0981(00)00331-2).

573 Lalèyè, P., Niyonkuru, C., Moreau, J., Teugels, G.G. 2003. Spatial and seasonal distribution of  
574 the ichthyofauna of Lake Nokoué, Bénin, west Africa. *African Journal of Aquatic Science*  
575 28(2): 151-161, DOI: 10.2989/16085910309503779

576 Lebigre, J.-M., 1983. Les mangroves des rias du littoral gabonais, essai de cartographie  
577 typologique. *Revue des Bois et Forêt des Tropiques* 199: 3–27.

578 Lebigre, J.-M., 1990. Les marais maritimes du Gabon et de Madagascar, contribution  
579 géographique à l'étude d'un milieu naturel tropical. State doctoral thesis, Bordeaux  
580 University 3, 703 p.

581 Lebigre, J.-M., Marius, C. 1984. Etude d'une séquence mangrove-tanne en milieu équatorial,  
582 Baie de la Mondah (Gabon). *Travaux et Documents de Géographie Tropicale* 51: 131-  
583 146.

584 Lebigre, J.-M., Marius, C., 1986. Etude phytopédologique des Mangroves et tannes de la  
585 Mondah (Gabon). *Etudes de Géographie Tropicale. Série Géographie Physique* 6: 1-44.

586 Leboulanger, C., Kolanou Biluka, L., Nzigou, A.-R., Djuidje Kenmogne, V., Happi, J.L.M.,  
587 Ngohang, F.E., Eleng, A.S., Ondo Zue Abaga, N., Bouvy, M. 2021. Urban inputs of fecal  
588 bacteria to the coastal zone of Libreville, Gabon, Central Western Africa. *Marine*  
589 *Pollution Bulletin* 168: 112478. <https://doi:10.1016/j.marpolbul.2021.112478>.

590 León, R.A., Racedo. J.B. 1985. Composition of fish communities in the lagoon and estuarine  
591 complex of Cartagena Bay, Ciénaga de Tesca and Ciénaga Grande de Santa Marta, Colombian  
592 Caribbean. Pages 536–556 in A. Yáñez-Arancibia, ed. Fish community ecology in

593 estuaries and coastal lagoons: towards an ecosystem integration. UNAM Press, Mexico.

594 Le Loeuff, P., von Cosel, R. 1998. Biodiversity patterns of the marine benthic fauna on the  
595 Atlantic coast of tropical Africa in relation to hydroclimatic conditions and  
596 paleogeographic events. *Acta Oecologica*, 19: 309-321 [https://doi.org/10.1016/S1146-](https://doi.org/10.1016/S1146-609X(98)80035-0)  
597 609X(98)80035-0.

598 Litvin, S.Y., Weinstein, M.P., Sheaves, M. Nagelkerken. I. 2018. What Makes Nearshore  
599 Habitats Nurseries for Nekton? An Emerging View of the Nursery Role Hypothesis.  
600 *Estuaries and Coasts* 41: 1539–1550 <https://doi.org/10.1007/s12237-018-0383-x>.

601 Loch, T.K., Riechers, M. 2021. Integrating indigenous and local knowledge in management  
602 and research on coastal ecosystems in the Global South: A literature review. *Ocean &*  
603 *Coastal Management* 212: 105821. <https://doi:10.1016/j.ocecoaman.2021.105821>.

604 Longhurst, A.R. 1965. A Survey of the Fish Resources of the Eastern Gulf of Guinea. *ICES*  
605 *Journal of Marine Science* 29(3): 302–334, <https://doi.org/10.1093/icesjms/29.3.302>

606 Loubens, G. 1966 Peuplement en poissons des eaux saumâtres et son origine. Paris (France):  
607 Faculté des Sciences, 29 p.

608 Margules, C.R., Pressey, R.L., 2000. Systematic conservation planning. *Nature* 405, 243–253.

609 McGlade, J.M., Cury, P., Koranteng, K.A., Hardmand-Mountford, N.J., 2002. The Gulf of  
610 Guinea large marine ecosystem: environmental forcing and sustainable development of  
611 marine resources. Amsterdam, Elsevier (eds) 428p

612 MEA. 2005. Ecosystems and Human Well-Being : Wetlands and Water Synthesis. World  
613 Resources Institute, Washington, DC. 80p.

614 Metcalfe, K., White, L., Lee, M. E., Fay, J. M., Abitsi, G., Parnell, R. J., Smith, R. J.,  
615 Agamboue, P. D., Bayet, J. P., Beh, J. H. M., Bongo, S., Boussamba, F., De Bruyne, G.,  
616 Cardiec, F., Chartrain, E., Collins, T., Doherty, P. D., Formia, A., Gately, M., Gnandji, M.  
617 S., ... Godley, B. J. 2021. Fulfilling global marine commitments; lessons learned from  
618 Gabon. *Conservation Letters* e12872. <https://doi.org/10.1111/conl.12872>

619 Moumaneix, C., Nkombe, R. 2017. Le « Gabon Vert », Pilier de l'émergence ? Exemple du  
620 Parc National de La Lopé : ressources, conflits et arrangements . *Bulletin de l'association*  
621 *de Géographes Français* 94(2): 330-352. <https://doi.org/10.4000/bagf.1506>

622 Mve Beh, J.-H., Yendze, C., Cardiec F., Mbega, J.-D., Le Loc'h, F. Liwouwou, J.-F. 2017. Les  
623 ressources halieutiques du Parc d'Akanda et des pêcheries périphériques. Bibliographic  
624 synthesis, Arc Emeraude project. 34 p.

625 Nagelkerken, I., Blaber, S.J.M., Bouillon, S., Green, P., Haywood, M., Kirton, L.G.,  
626 Meynecke, J.O. et al. 2008. The habitat function of mangroves for terrestrial and marine  
627 fauna: a review. *Aquatic Botany* 89 (2): 155–85.  
628 <https://doi.org/10.1016/j.aquabot.2007.12.007>.

629 Nieto, K., Melin, F. 2017. Variability of chlorophyll-a concentration in the Gulf of Guinea and  
630 its relation to physical oceanographic variables. *Progress in Oceanography* 151: 97-115.  
631 <http://dx.doi.org/10.1016/j.pocean.2016.11.009>

632 Ona Ona, J. 2019. Gestion durable des ressources halieutiques en Afrique Atlantique Centre-  
633 Est : Cameroun-Congo-Gabon : perspective d'une politique de régulation sous-régionale.  
634 PhD Thesis, Nantes, 311p. Available from <https://www.theses.fr/2019NANT2051>

635 Oribhador, B.J, Ezenwa, B., 2005. Inventory of fisheries and fishes of the Lagos Lagoon,  
636 Lagos, Nigeria. *Tropical Freshwater Biology* 14(1): 16-36

637 Panfili, J., Thior, D., Ecoutin, J.-M., Ndiaye, P., Albaret, J.-J. 2006. Influence of salinity on the  
638 size at maturity for fish species reproducing in contrasting West African estuaries. *Journal*  
639 *of Fish Biology* 69: 95–113

640 Pielou, E.C. 1969. An introduction to mathematical ecology New York: Interscience  
641 Publishers.

642 Potter, I.C., Tweedley, J.R., Elliott, M., Whitfield, A.K. 2015. The ways in which fish use  
643 estuaries: a refinement and expansion of the guild approach. *Fish and Fisheries* 16: 230-  
644 239

- 645 Pottier, P., Ovono, Z.M., Faure, F.E., Bignoumba, G.-S. 2017. *Les régions littorales du*  
646 *Gabon ; éléments de réflexion pour une planification stratégique du territoire*. Edited by  
647 LETG-Nantes Géolittomer (Nantes) & Raponda Walker. LETG-Nantes. Gabon.
- 648 R Core Team, 2022. R: a Language and Environment for Statistical Computing. R Foundation  
649 for Statistical Computing, Vienna, Austria. URL. <http://www.Rproject.org>
- 650 Sheridan, P., Hays, C. 2003. Are mangroves nursery habitat for transient fishes and decapods ?  
651 *Wetlands* 23 (2): 449–458.
- 652 Sosa-Lopez, A., Mouillot, D., Ramos-Miranda, J., Flores-Hernandez, D., Do Chi, T. 2007. Fish  
653 species richness decreases with salinity in tropical coastal lagoons. *Journal of*  
654 *Biogeography* 34:52–61.
- 655 Stiassny, M.L.J., Teugels, G.G., Hopkins, C.D. 2007. The Fresh and Brackish Water Fishes of  
656 Lower Guinea, West-Central Africa. Volume I (800pp). Paris : IRD Éditions.
- 657 Thomas, N., Lucas, R., Bunting, P., Hardy, A., Rosenqvist, A., Simard, M. 2017. Distribution  
658 and drivers of global mangrove forest change, 1996–2010. *PLoS ONE* 12(6): e0179302.  
659 <https://doi.org/10.1371/journal.pone.0179302>
- 660 Tomlinson, P. 2016. The Botany of Mangroves, 2nd Edn. Cambridge: Cambridge University  
661 Press. doi: 10.1017/CBO9781139946575
- 662 UNEP. 2014. The importance of mangroves to people: a call to action. van Bochove, J.,  
663 Sullivan, E., Nakamura, T. United Nations Environment Programme World Conservation  
664 Monitoring Centre. Cambridge. 128pp.
- 665 Van de Weghe, J.-P., 2005. Les Parcs Nationaux du Gabon. Akanda et Pongara: Plages et  
666 mangroves. Gabon Wildlife Conservation Society, Libreville, Gabon. 208 p.
- 667 Voituriez, B., Herbland, A. 1982. Comparaison des systèmes productifs de l'Atlantique tropical  
668 Est: dômes thermiques, upwelling côtier et upwelling équatorial. *Rapports et Procès-*  
669 *Verbaux des réunions du Conseil International pour l'Exploration de la Mer* 180: 11-130

670 Vorsatz, L.D., Pattrick, P., Porri, F. 2021. Ecological scaling in mangroves: The role of  
671 microhabitats for the distribution of larval assemblages. *Estuarine, Coastal and Shelf*  
672 *Science* 253: 107318. <https://doi.org/10.1016/j.ecss.2021.107318>

673 Weeks, R., Jupiter, S.D. 2013. Adaptive comanagement of a marine protected area network in  
674 Fiji. *Conservation Biology* 27: 1234-1244. <https://doi.org/10.1111/cobi.12153>

675 Whitfield, A.K. 1988. The fish community of the Swartvlei estuary and the influence of food  
676 availability on resource utilization. *Estuaries* 11: 160–170.  
677 <https://doi.org/10.2307/1351968>

678 Whitfield, A.K. 2005. Preliminary documentation and assessment of fish diversity in sub-  
679 Saharan African estuaries. *African Journal of Marine Science* 27(1): 307-324,  
680 <https://doi.org/10.2989/18142320509504089>

681 Whitfield, A.K., Attwood, C.G., Cowley, P.D., Lamberth, S.J., Mann, B.Q., 2020. No-take  
682 estuarine-protected areas: The missing armor for the conservation of fishes. *Koedoe*  
683 62(1): a1648. <https://doi.org/10.4102/koedoe.v62i1.1648>

684 Wiens, J.A. 1989. Spatial scaling in ecology. *Functional Ecology* 3: 385–397.  
685 <https://doi.org/10.2307/2389612>

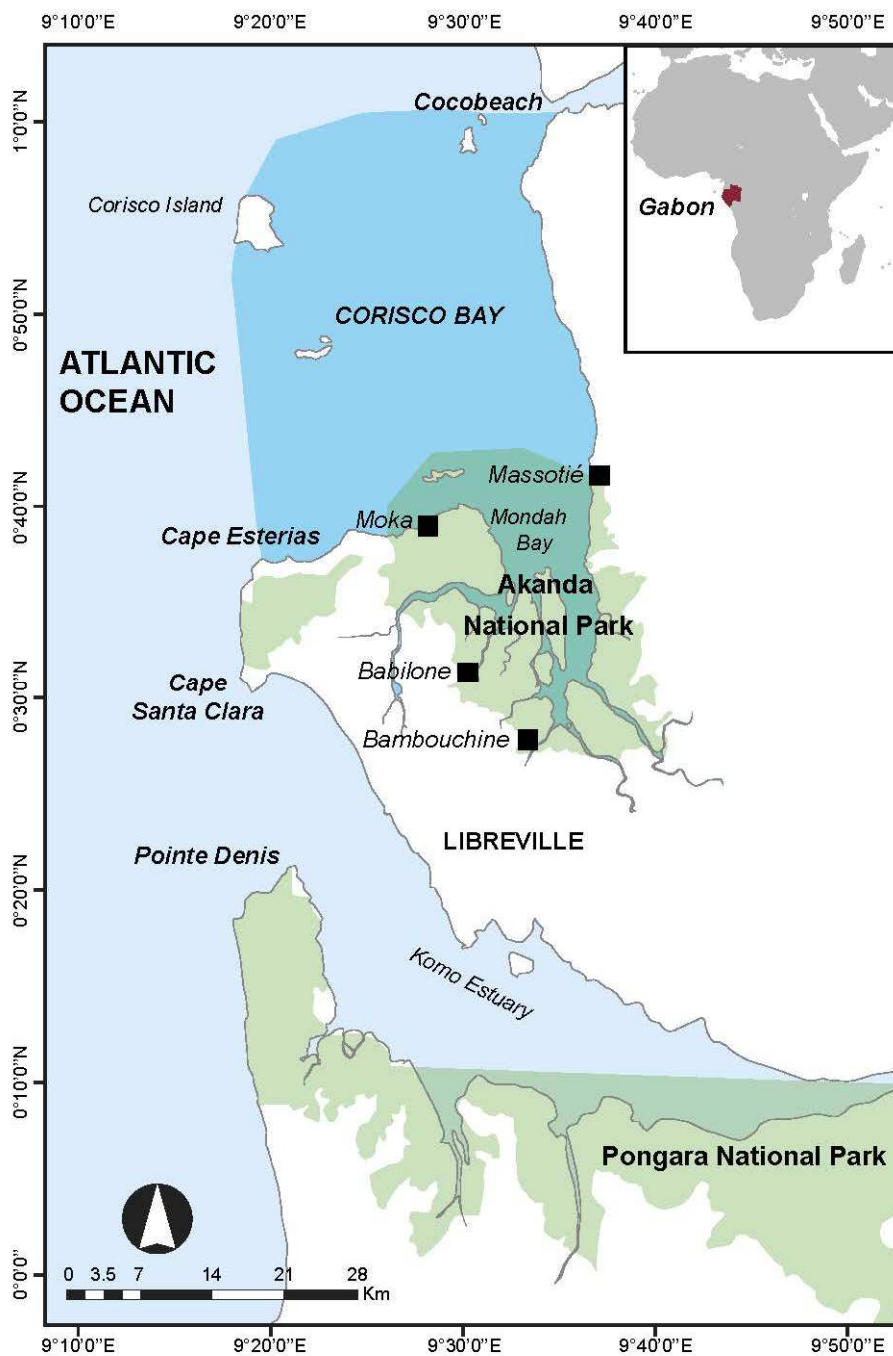
686 Wood, L.J., Fish, L., Laughren, J., Pauly, D. 2008. Assessing progress towards global marine  
687 protection targets: shortfalls in information and action. *Oryx* 42: 340-351. <https://doi.org/10.1017/S003060530800046X>

688

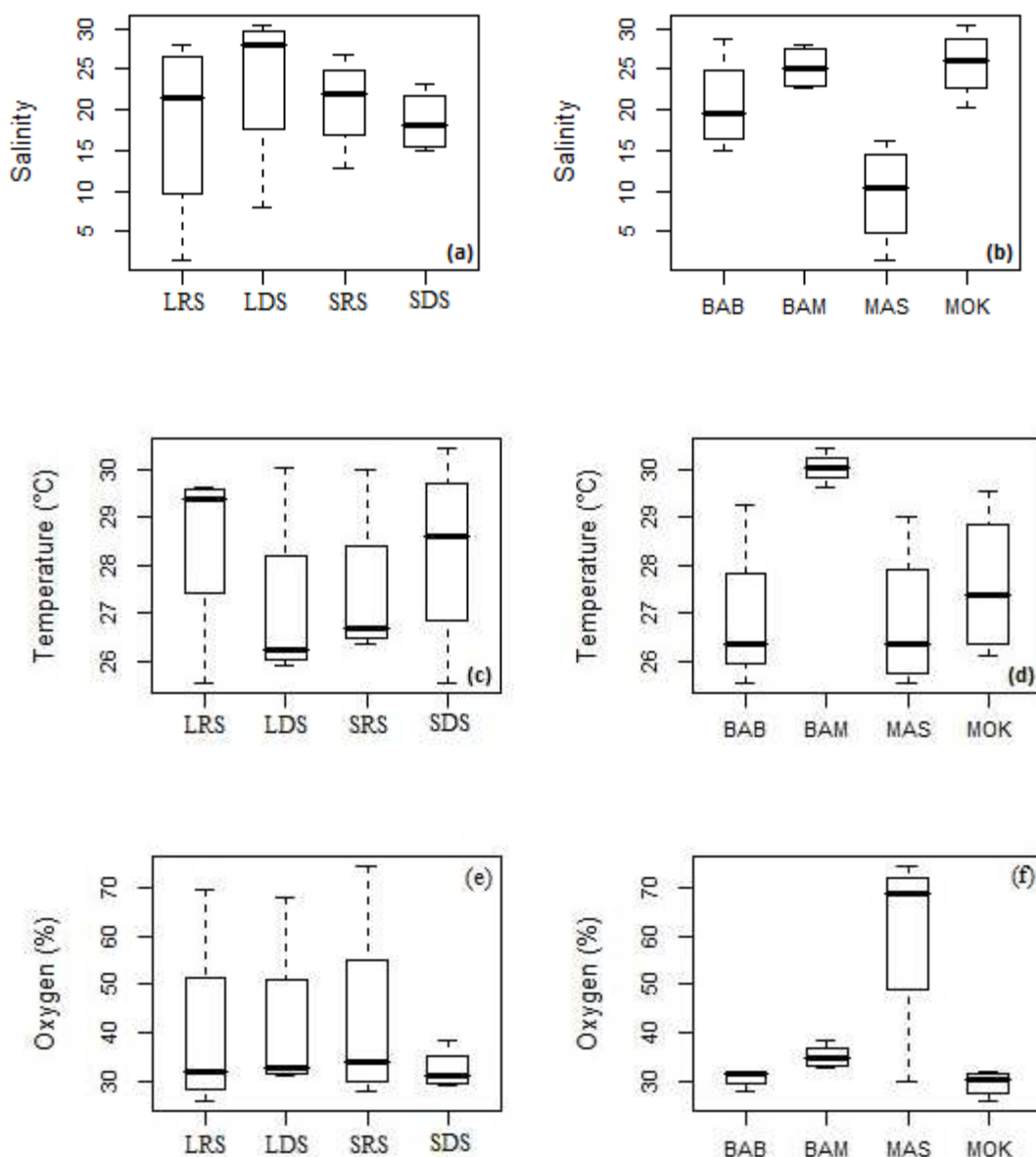
689 Worthington, T., Spalding, M. 2018. Mangrove restoration potential: a global map highlighting  
690 a critical opportunity. UICN, University of Cambridge, TNC report. 34 p.  
691 <https://doi.org/10.17863/CAM.39153>.

692 Yáñez-Arancibia, A. 1978. Taxonomy, ecology and structure of fish communities in coastal  
693 lagoons with ephemeral inlets on the Pacific coast of Mexico. Instituto de Ciencias del  
694 Mar y Limnología, Universidad Nacional Autónoma de México, Publicaciones  
695 Especiales 2: 1–306.

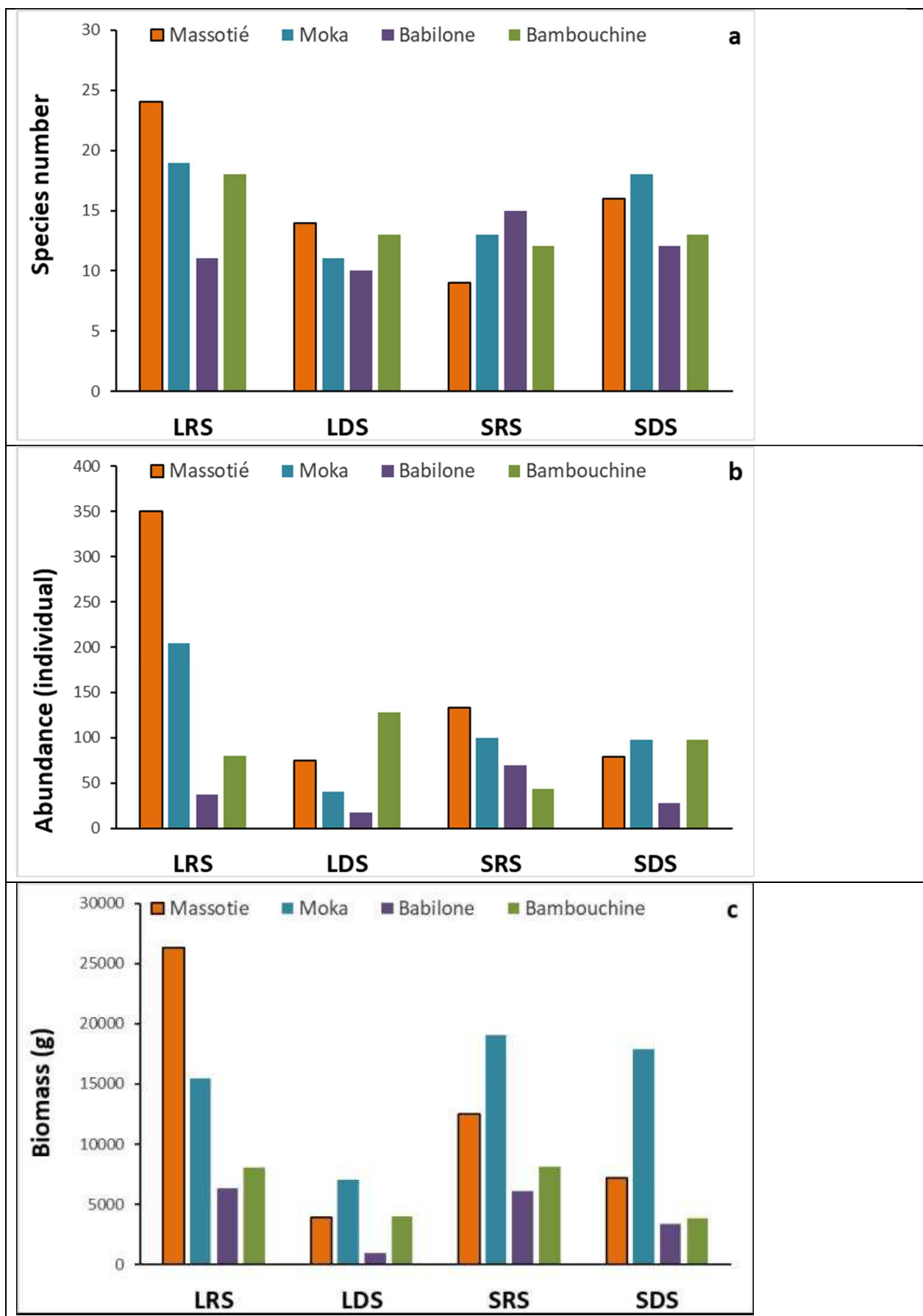
696  
697



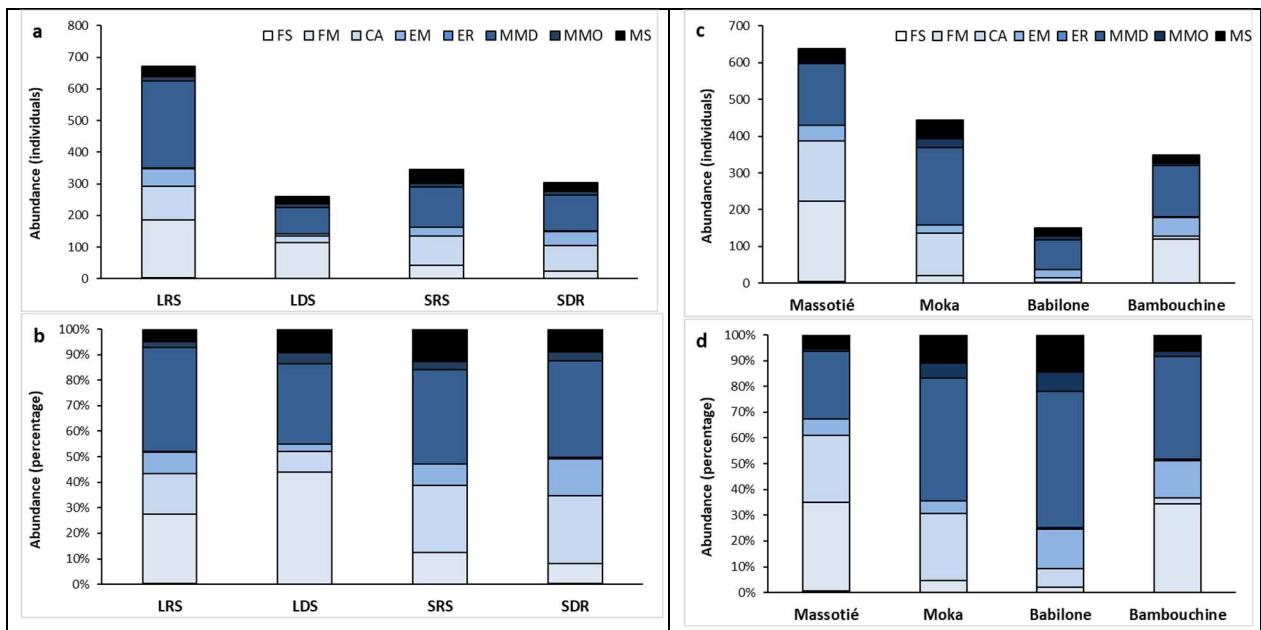
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699 **Figure 1:** Location of the four sampling sites (Bambouchine, Babilone, Massotié and Moka) in  
700 the Mondah bay, in Akanda National Park. The green color corresponds to the national parks.



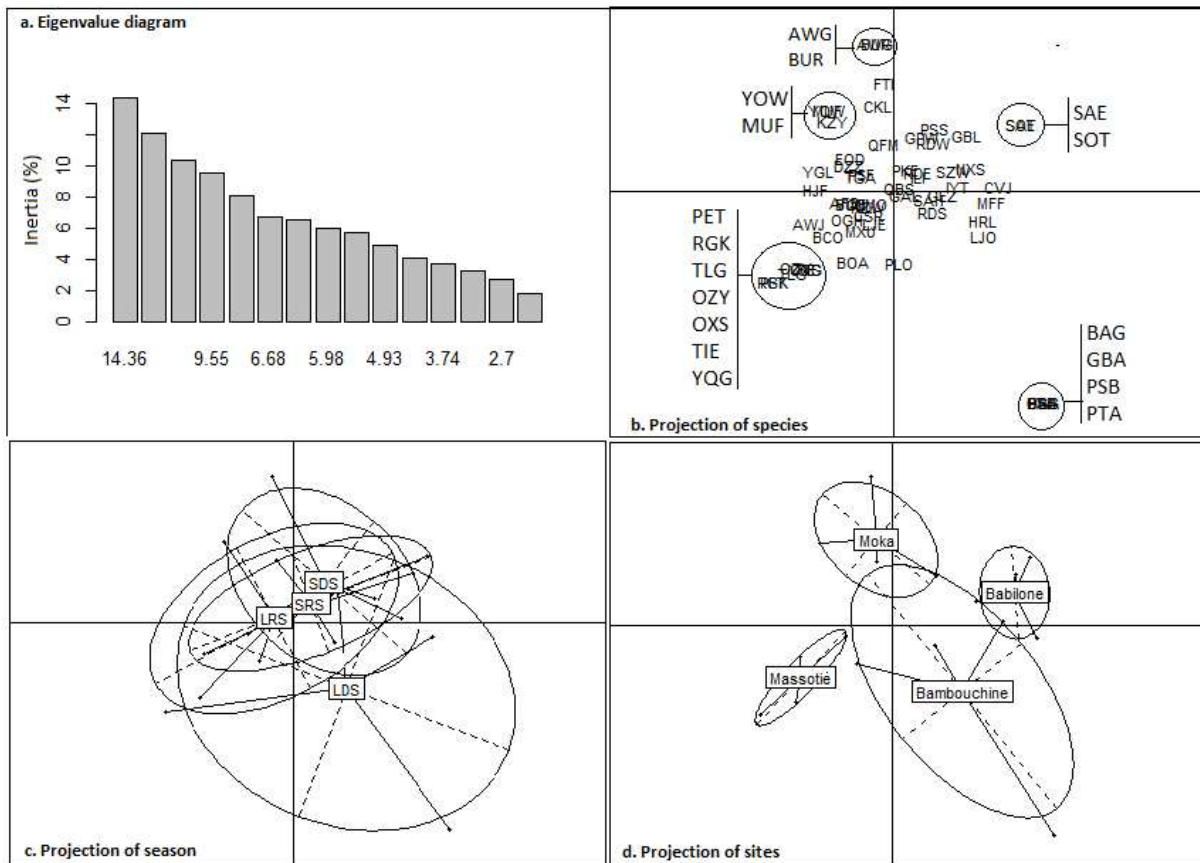
702 **Figure 2:** Box plots showing the seasonal (left) and spatial (right) variations in the main  
 703 environmental parameters. The bottom and top edges of the boxes are located at the sample  
 704 25th and 75th percentiles. The center horizontal line is drawn at the 50th percentile (median).  
 705 The whiskers are drawn, respectively, from the box to the 10th and 90th percentiles. (a), (b):  
 706 salinity; (c), (d): temperature (°C); (e), (f): dissolved oxygen (% saturation). LRS: long rainy  
 707 season, LDS: long dry season, SRS: short rainy season, SDS: short dry season (SDS), BAB:  
 708 Babilone, BAM: Bambouchine, MAS: Massotié, MOK: Moka.



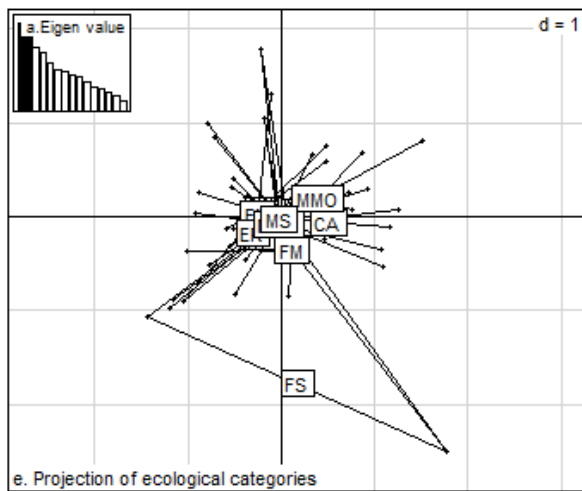
710 **Figure 3:** number of species (a), abundance (b), and biomass (c) in function of hydroclimatic  
711 season and sampling areas. LRS: Long Rainy Season, LDS: Long Dry Season, SRS: Short  
712 Rainy Season, SDS: Short Dry Season.  
713



715  
 716 **Figure 4:** Mean fish abundance by ecological categories by season (absolute (a) and relative  
 717 (b) abundances) and by sampling station (absolute (c) and relative (d) abundances). LRS: Long  
 718 Rainy Season, LDS: Long Dry Season, SRS: Short Rainy Season, SDS: Short Dry Season. FS:  
 719 Freshwater Stragglers, FM: Freshwater Migrants, CA: Catadromous, EM: Estuarine Migrants,  
 720 ER: Estuarine Residents, MMD: Marine Estuarine-Dependent, MMO: Marine Estuarine-  
 721 Opportunist, MS: Marine Stragglers.



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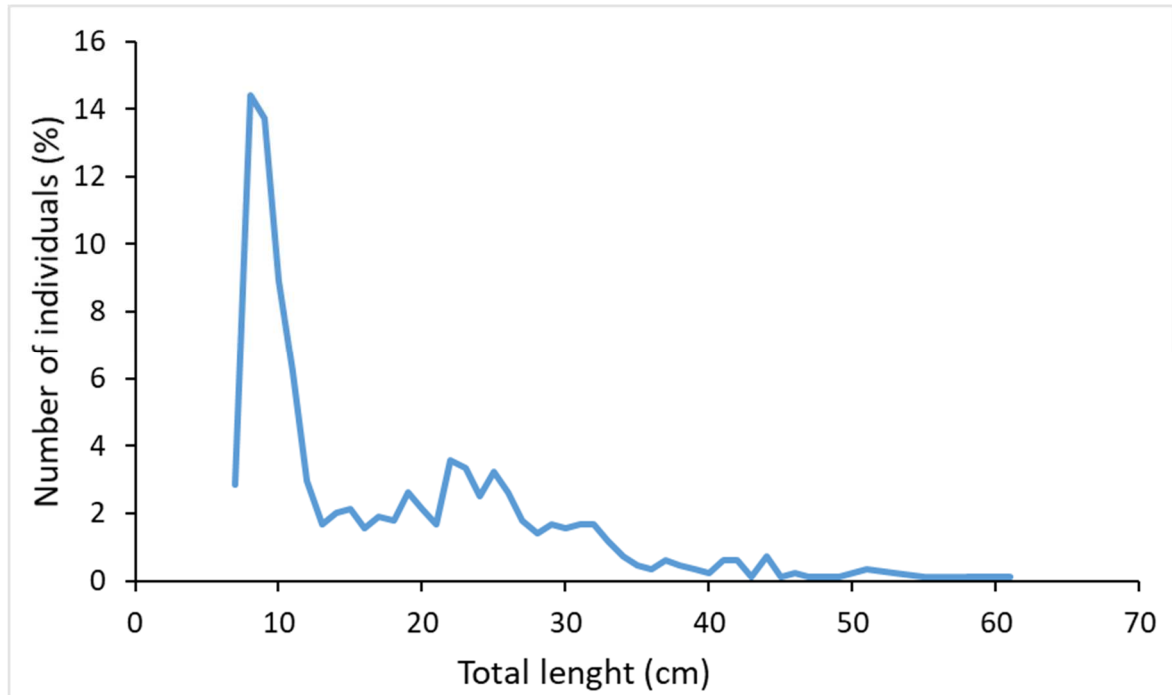
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728 **Figure 5:** Correspondence analysis on the mangrove area of Akanda National Park on the  
 729 factorial plane 1-2. a) projection of eigenvalues, b) projection of species (59 species, code see  
 730 table 2), c) projection of seasons (LRS: long rainy season, LDS: long dry season, SRS: short  
 731 rainy season, SDS: short dry season), d) projection of sites, e) projection of ecological  
 732 categories FS: Freshwater Stragglers, FM: Freshwater Migrants, CA: Catadromous, EM:

733 Estuarine Migrants, ER: Estuarine Residents, MMD: Marine Estuarine-Dependent, MMO:

734 Marine Estuarine-Opportunist, MS: Marine Stragglers.,



736  
 737 **Figure 6:** Size spectrum (percentage of individuals) of High Commercial Value species with  
 738 more than 50 individuals (6 species: *Pseudolithus elongatus*, *Parachelon grandisquamis*,  
 739 *Eucinostomus melanopterus*, *Chrysichtys nigrodigitatus*, *Neochelon falcipinnis*, *Polydactylus*  
 740 *quadrifilis*). N = 839

741 **Table 2:** List of the 59 fish species collected in the four sampling stations in Akanda at the four  
742 hydrological seasons from May 2017 to March 2018, sorted by decreasing abundance, family,  
743 FAO species code, ecological category (Ecolo), percentage of occurrence, abundance and  
744 percentage of abundance, biomass and percentage of biomass.

745  
746 FS: Freshwater Stragglers, FM: Freshwater Migrants, CA: Catadromous, EM: Estuarine Migrants, ER: Estuarine  
747 Residents, MMD: Marine Estuarine-Dependent, MMO: Marine Estuarine-Opportunist, MS: Marine Stragglers.

Species	Family	Code	Ecolo	O (%)	A	A (%)	B	B (%)
<i>Pseudotolithus elongatus</i>	Sciaenidae	AFS	CA	69	289	18.29	36276	24.16
<i>Pellonula leonensis</i>	Clupeidae	PLO	FM	56	243	15.38	1777	1.18
<i>Parachelon grandisquamis</i>	Mugilidae	KZW	MMD	88	231	14.62	4840	3.22
<i>Ilisha africana</i>	Pristigasteridae	ILI	MMD	81	149	9.43	6001	4.00
<i>Eucinostomus melanopterus</i>	Gerreidae	MFF	MMD	50	97	6.14	5125	3.41
<i>Chrysoscthus nigrodigitatus</i>	Claroteidae	CSR	FM	63	87	5.51	31798	21.17
<i>Neochelon falcipinnis</i>	Mugilidae	KZY	MMD	25	78	4.94	637	0.42
<i>Monodactylus sebae</i>	Monodactylidae	QBS	EM	75	66	4.18	2490	1.66
<i>Polydactylus quadrifilis</i>	Polynemidae	TGA	MS	75	57	3.61	10148	6.76
<i>Pellonula vorax</i>	Clupeidae	OZY	FM	19	26	1.65	231	0.15
<i>Sarotherodon melanotheron</i>	Cichlidae	SAH	EM	19	22	1.39	927	0.62
<i>Plectorhinchus macrolepis</i>	Haemulidae	GBL	MMD	50	21	1.33	15874	10.57
<i>Epinephelus aeneus</i>	Serranidae	GPW	MMO	50	17	1.08	877	0.58
<i>Pomadasys perotai</i>	Haemulidae	PKE	MMO	38	16	1.01	766	0.51
<i>Porogobius schlegelii</i>	Gobiidae	OGH	EM	38	14	0.89	104	0.07
<i>Chaetodipterus lippei</i>	Ephippidae	HRL	MS	38	13	0.82	828	0.55
<i>Pseudotolithus senegalensis</i>	Sciaenidae	PSS	MS	31	11	0.70	536	0.36
<i>Ethmalosa fimbriata</i>	Clupeidae	BOA	CA	31	10	0.63	208	0.14
<i>Galeoides decadactylus</i>	Polynemidae	GAL	MMO	38	9	0.57	466	0.31
<i>Aplocheilichthys spilauchen</i>	Poeciliidae	AFS	EM	25	8	0.51	34	0.02
<i>Eleotris daganensis</i>	Eleotridae	EOD	EM	19	8	0.51	393	0.26
<i>Periophthalmus barbarus</i>	Gobiidae	FTI	EM	19	8	0.51	76	0.05

<i>Citharichthys stampflii</i>	Paralichthyidae	IYT	MMD		31	7	0.44	55	0.04
<i>Fontitrygon margaritella</i>	Dasyatidae	RDE	MMD		31	7	0.44	8158	5.43
<i>Lutjanus goreensis</i>	Lutjanidae	LJO	MS		31	7	0.44	1865	1.24
<i>Pseudotolithus senegallus</i>	Sciaenidae	CKL	MS		13	6	0.38	1038	0.69
<i>Lutjanus dentatus</i>	Lutjanidae	LJE	MS		19	5	0.32	697	0.46
<i>Nematogobius maindroni</i>	Gobiidae	NMO	EM		25	5	0.32	29	0.02
<i>Strongylura senegalensis</i>	Belonidae	SZW	MS		19	5	0.32	220	0.15
<i>Hemichromis elongatus</i>	Cichlidae	HJF	FM		13	4	0.25	20	0.01
<i>Lutjanus endecacanthus</i>	Lutjanidae	QFM	MS		19	4	0.25	1447	0.96
<i>Pomadasys jubelini</i>	Haemulidae	BUR	MMO		6	4	0.25	796	0.53
<i>Coptodon guineensis</i>	Cichlidae	TLG	EM		13	3	0.19	225	0.15
<i>Eleotris senegalensis</i>	Eleotridae	DZZ	EM		19	3	0.19	22	0.01
<i>Gerres nigri</i>	Gerreidae	GEZ	ER		19	3	0.19	63	0.04
<i>Mugil cephalus</i>	Mugilidae	MUF	MS		6	3	0.19	21	0.01
<i>Odaxothrissa ansorgii</i>	Clupeidae	OXS	FS		6	3	0.19	39	0.03
<i>Syacium guineensis</i>	Paralichthyidae	YGL	MS		13	3	0.19	17	0.01
<i>Bryconalestes longipinnis</i>	Alestidae	BCO	FM		13	2	0.13	18	0.01
<i>Caranx hippos</i>	Carangidae	CVJ	MS		13	2	0.13	181	0.12
<i>Carlarius parkii</i>	Ariidae	AWJ	MMD		6	2	0.13	450	0.30
<i>Cynoglossus senegalensis</i>	Cynoglossidae	YOE	MMD		6	2	0.13	324	0.22
<i>Fontitrygon margarita</i>	Dasyatidae	RDS	MMD		13	2	0.13	2708	1.80
<i>Sardinella maderensis</i>	Clupeidae	SAE	MMO		6	2	0.13	18	0.01
<i>Sphyaena afra</i>	Sphyaenidae	BAG	MS		6	2	0.13	969	0.65
<i>Arnoglossus capensis</i>	Bothidae	RGK	MS		6	1	0.06	4	0.00
<i>Caranx senegallus</i>	Carangidae	NXS	MS		6	1	0.06	102	0.07
<i>Cynoglossus browni</i>	Cynoglossidae	YOW	MMD		6	1	0.06	137	0.09
<i>Cynoglossus monodi</i>	Cynoglossidae	YQG	MS		6	1	0.06	39	0.03
<i>Enteromius holotaenia</i>	Cyprinidae	BUO	FS		6	1	0.06	5	0.00
<i>Fontitrygon ukpam</i>	Dasyatidae	RDW	FM		6	1	0.06	2060	1.37
<i>Gymnothorax afer</i>	Muraenidae	AWG	MS		6	1	0.06	1310	0.87
<i>Myrichthys pardalis</i>	Ophichthidae	MXU	MS		6	1	0.06	284	0.19
<i>Pentanemus quinquarius</i>	Polynemidae	PET	MS		6	1	0.06	5	0.00
<i>Platybelone argalus</i>	Belonidae	PTA	MS		6	1	0.06	37	0.02
<i>Psettodes belcheri</i>	Psettodidae	SOT	MS		6	1	0.06	145	0.10
<i>Psettodes bennettii</i>	Psettodidae	PSB	MS		6	1	0.06	273	0.18
<i>Sphyaena barracuda</i>	Sphyaenidae	GBA	MS		6	1	0.06	380	0.25
<i>Trachinotus teraia</i>	Carangidae	TIE	MMD		6	1	0.06	5600	3.73

748 **Table 3:** Total fish species richness (S), mean fish species richness (Mean S), mean Shannon  
 749 diversity index (mean H'), mean equitability index (mean J), mean abundance (Mean A) and  
 750 mean biomass (Mean B) by season and site. Differences were tested with a one factor ANOVA  
 751 tests (LRS = Long Rainy Season; GSS = Long Dry Season; SDS = Short Rainy Season; SDS =  
 752 Short Dry Season).

753 Standard deviations are presented between brackets  
 754

	Season				Site			
	LRS	LDS	SDS	SRS	MAS	MOK	BAB	BAM
<b>S</b>	37	29	29	35	26	31	36	33
<b>Mean S</b>	19.00 (5.35)	13.00 (1.83)	13.25 (2.50)	15.75 (2.75)	16.75 (6.24)	16.25 (3.86)	13.00 (2.16)	15.00 (2.71)
<b>ANOVA test</b>	p = 0.091, F = 2.720, Df = 3				p = 0.582, F = 0.678, Df = 3			
<b>Mean H'</b>	2.037 (0.247)	1.812 (0.450)	1.965 (0.330)	1.951 (0.391)	1.851 (0.271)	2.037 (0.068)	2.075 (0.171)	1.803 (0.617)
<b>ANOVA test</b>	p = 0.846, F = 0.270, Df = 3				p = 0.846, F = 0.592, Df = 3			
<b>Mean J</b>	0.719 (0.096)	0.739 (0.216)	0.786 (0.096)	0.729 (0.149)	0.688 (0.060)	0.761 (0.092)	0.841 (0.091)	0.683 (0.220)
<b>ANOVA test</b>	p = 0.919, F = 0.164, Df = 3				p = 0.326, F = 1.280, Df = 3			
<b>Mean A</b>	168.00 (140.71)	65.00 (48.30)	86.25 (38.91)	73.75 (33.07)	159.25 (129.89)	110.75 (68.72)	37.75 (22.38)	87.25 (35.53)
<b>chi-squared test</b>	chi-squared = 5.393, df = 3 p-value = 0.145				chi-squared = 6.833, df = 3 p-value = 0.077			
<b>Mean B</b>	14.04 (9.08)	3.96 (2.50)	11.44 (5.70)	8.08 (6.72)	12.47 (9.88)	14.84 (5.40)	4.20 (2.56)	6.01 (2.41)
<b>chi-squared test</b>	chi-squared = 4.855, df = 3 p-value = 0.182				chi-squared = 2.103, df = 3 p-value = 0.551			

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756  
 757 **Table 4:** Number of individuals, minimum and maximum total lengths, size at sexual maturity  
 758 (L<sub>50</sub>) and proportion of individuals below L<sub>50</sub> for the 6 high commercial value species with  
 759 numbers above 50 individuals. \* As no L<sub>50</sub> was available for *Eucinostomus melanopterus* we  
 760 approximate its L<sub>50</sub> based on another gerreidae *Gerres nigri*.

Species	Number of individuals	Minimal total length (cm)	Maximal total length (cm)	L <sub>50</sub> * (cm) reference	Lt < L <sub>50</sub> (%)
<i>Chrysichtys nigrodigitatus</i>	87	8	62	33.4 Ajagbe et al., 2021	<b>57.5</b>
<i>Eucinostomus melanopterus</i> *	97	7	13	12.1 Panfili et al 2006	<b>99.0</b>
<i>Neochelon falcipinnis</i>	78	8	25	27.9 Djiadji et al 2006	<b>100</b>
<i>Parachelon grandisquamis</i>	231	8	32	25.1 Panfili et al 2006	<b>98.7</b>
<i>Polydactylus quadrifilis</i>	57	12	49	67.5 Konan et al 2019	<b>100.0</b>
<i>Pseudotolithus elongatus</i>	289	8	53	23.8 Panfili et al 2006	<b>91.0</b>

761 **APPENDIX**

762  
 763 **Appendix 1:** Mean value, standard deviation (SD) and range are given for surface temperature  
 764 (°C) and dissolved oxygen (%) in the four sampling sites of Akanda National Parc for 2017-  
 765 2018 (LRS: Long Rainy Season, LDS: Long Dry Season, SDS: Short Dry Season, SRS: Short  
 766 Rainy Season)

		Season				Site			
		LRS	LDS	SDS	SRS	Babilone	Bambouchine	Massotié	Moka
<b>Salinity</b>	Mean (±SD)	18.9 (±10.2)	23.7 (±9.1)	21.0 (±5.2)	18.5 (±3.5)	20.5 (±5.1)	25.3 (±2.8)	9.5 (±5.8)	25.6 (±3.8)
	Range	1.2-28.8	5.6-30.5	10.8-26.8	14.4-24.8	14.4-28.7	19.5-28.8	1.2-17.3	19.6-30.5
	chi-squared test	chi-squared = 2.3824, df = 3, p-value = 0.4969				chi-squared = 9.0221, df = 3, <b>p-value = 0.029</b>			
<b>Temperature (°C)</b>	Mean (±SD)	28.5 (±1.6)	27.2 (±1.8)	27.5 (±1.7)	28.2(±2.8)	27.0 (±2.4)	29.8 (±0.9)	26.8 (±1.5)	27.6 (±1.4)
	Range	25.2-29.9	25.6-30.6	28.5-30.6	20.2-31.5	20.2-29.5	28.5-31.5	25.2-29.8	26.1-29.7
	chi-squared test	chi-squared = 0.61765, df = 3, p-value = 0.8924				chi-squared = 9.0662, df = 3, <b>p-value = 0.02842</b>			
<b>Oxygen (%)</b>	Mean (±SD)	37.2 (±19.8)	39.5 (±18.5)	41.0 (±20.4)	32.2 (±10.9)	30.0 (±7.7)	32.5 (±14.1)	60.4 (±19.6)	29.4 (±3.8)
	Range	11.0-73.3	12.6-70.7	19.0-85.7	14.2-50.6	19.0-40.5	11.0-50.6	22.3-85.7	18.0-32.7
	chi-squared test	chi-squared = 0.28676, df = 3, p-value = 0.9625				chi-squared = 12.397, df = 3, <b>p-value = 0.00614</b>			

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768  
 769 **Appendix 2:** Minimum, maximum and mean±standard deviation size (total length) of the 59  
 770 fish species caught in the mangrove area of Akanda National Park during this study. Fish  
 771 commercial value: high (HCV), medium (MCV) and no commercial value (NCV)

772

Family	Species	Fish commercial value	Total length (cm)		
			Minimum	Maximum	Mean ± standard deviation
Poeciliidae	<i>Aplocheilichthys spilauchen</i>	NCV	7	9	7.6±0.6
Bothidae	<i>Arnoglossus capensis</i>	MCV	8	8	7.7
Alestidae	<i>Bryconalestes longipinnis</i>	NCV	9	10	9.6±0.5
Carangidae	<i>Caranx hippos</i>	HCV	19	20	19.5±1.2
Carangidae	<i>Caranx senegallus</i>	HCV	22	22	22.0
Ariidae	<i>Carlarius parkii</i>	HCV	27	32	29.6±3.6
Ephippidae	<i>Chaetodipterus lippei</i>	HCV	7	36	13.4±7.0
Claroteidae	<i>Chrysoscthyus nigrodigitatus</i>	HCV	8	62	30.8±13.8
Paralichthyidae	<i>Citharichthys stampflii</i>	MCV	7	14	9.3±2.5
Cichlidae	<i>Coptodon guineensis</i>	MCV	6	22	12.2±8.6
Cynoglossidae	<i>Cynoglossus browni</i>	HCV	36	36	35.5
Cynoglossidae	<i>Cynoglossus monodi</i>	HCV	24	24	23.7
Cynoglossidae	<i>Cynoglossus senegalensis</i>	HCV	31	41	36.1±7.2
Eleotridae	<i>Eleotris daganensis</i>	NCV	9	28	12.9±6.4
Eleotridae	<i>Eleotris senegalensis</i>	NCV	9	10	9.1±0.5
Cyprinidae	<i>Enteromius holotaenia</i>	NCV	8	8	8.2
Serranidae	<i>Epinephelus aeneus</i>	HCV	9	24	14.6±4.7
Clupeidae	<i>Ethmalosa fimbriata</i>	HCV	8	19	11.8±3.8
Gerreidae	<i>Eucinostomus melanopterus</i>	MCV	7	13	8.6±0.9
Dasyatidae	<i>Fontitrygon margarita</i>	MCV	53	110	81.7±40.3
Dasyatidae	<i>Fontitrygon margaritella</i>	MCV	70	110	84.7±13.6
Dasyatidae	<i>Fontitrygon ukpam</i>	MCV	87	87	86.5
Polynemidae	<i>Galeoides decadactylus</i>	HCV	11	26	16.3±4.5
Gerreidae	<i>Gerres nigri</i>	MCV	9	16	11.3±3.7
Muraenidae	<i>Gymnothorax afer</i>	NCV	87	87	86.7
Cichlidae	<i>Hemichromis elongatus</i>	MCV	7	9	7.8±0.8
Pristigasteridae	<i>Ilisha africana</i>	MCV	9	28	17.4±3.7
Lutjanidae	<i>Lutjanus dentatus</i>	HCV	7	33	18.2±10
Lutjanidae	<i>Lutjanus endecacanthus</i>	HCV	21	36	27.1±6.1
Lutjanidae	<i>Lutjanus goreensis</i>	HCV	12	38	24.7±8.5
Monodactylidae	<i>Monodactylus sebae</i>	MCV	5	29	10.6±3.6
Mugilidae	<i>Mugil cephalus</i>	HCV	8	10	9.1±0.9
Ophichthidae	<i>Myrichthys pardalis</i>	NCV	71	71	70.8
Gobiidae	<i>Nematogobius maindroni</i>	NCV	8	10	8.8±0.8
Mugilidae	<i>Neochelon falcipinnis</i>	HCV	8	25	9.4±2.1
Clupeidae	<i>Odaxothrissa ansorgii</i>	NCV	12	13	12.0±0.4
Mugilidae	<i>Parachelon grandisquamis</i>	HCV	8	32	11.8±4.0

Clupeidae	<i>Pellonula leonensis</i>	NCV	6	13	10.0±1.2
Clupeidae	<i>Pellonula vorax</i>	NCV	9	13	10.6±0.8
Polynemidae	<i>Pentanemus quinquarius</i>	HCV	10	10	10.2
Gobiidae	<i>Periophthalmus barbarus</i>	NCV	9	14	10.9±1.8
Belonidae	<i>Platybelone argalus</i>	NCV	21	21	21.0
Haemulidae	<i>Plectorhinchus macrolepis</i>	HCV	15	53	30.4±12.5
Polynemidae	<i>Polydactylus quadrifilis</i>	HCV	12	49	27.4±8.4
Haemulidae	<i>Pomadasys jubelini</i>	HCV	19	30	23.4±5.0
Haemulidae	<i>Pomadasys perotaei</i>	HCV	7	22	14.3±5.6
Gobiidae	<i>Porogobius schlegelii</i>	NCV	9	12	10.0±0.9
Psettodidae	<i>Psettodes belcheri</i>	MCV	23	23	23.2
Psettodidae	<i>Psettodes bennettii</i>	MCV	29	29	28.9
Sciaenidae	<i>Pseudotolithus elongatus</i>	HCV	8	53	22.2±7.3
Sciaenidae	<i>Pseudotolithus senegalensis</i>	HCV	9	27	17.2±5.6
Sciaenidae	<i>Pseudotolithus senegallus</i>	HCV	17	35	25.8±6.9
Clupeidae	<i>Sardinella maderensis</i>	MCV	10	12	10.6±1.2
Cichlidae	<i>Sarotherodon melanotheron</i>	MCV	6	21	11.3±4.2
Sphyraenidae	<i>Sphyraena afra</i>	HCV	33	53	42.9±13.8
Sphyraenidae	<i>Sphyraena barracuda</i>	HCV	41	41	41.3
Belonidae	<i>Strongylura senegalensis</i>	NCV	30	38	35.0±2.8
Paralichthyidae	<i>Syacium guineensis</i>	MCV	8	11	8.8±1.7
Carangidae	<i>Trachinotus teraia</i>	HCV	43	43	42.5

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<b>Families</b>	<b>Species</b>	<b>Bibliographic reference</b>
ACANTHURIDAE	<i>Acanthurus monroviae</i> (Steindachner, 1876)	<i>g</i>
ALESTIDAE	<i>Bryconalestes longipinnis</i> (Günther, 1864)	<i>f, h</i>
ARIIDAE	<i>Carlarius gigas</i> (Boulenger, 1911)	<i>b</i>
	<i>Carlarius parkii</i> (Günther, 1864)	<i>g, h</i>
BELONIDAE	<i>Platybelone argalus</i> (Lesueur, 1821)	<i>a, b, f, g</i>
	<i>Strongylura senegalensis</i> (Valenciennes, 1846)	<i>f, h</i>
	<i>Tylosurus acus rafale</i> (Lacepède, 1803)	<i>b</i>
BOTHIDAE	<i>Arnoglossus capensis</i> Boulenger, 1898	<i>b, h</i>
CARANGIDAE	<i>Alectis alexandrina</i> (Geoffroy St. Hilaire, 1817)	<i>a, b, f, g</i>
	<i>Alectis ciliaris</i> (Bloch, 1787)	<i>b</i>
	<i>Caranx hippos</i> (Linnaeus, 1766)	<i>b, f, g, h</i>
	<i>Caranx lugubris</i> (Poey, 1860)	<i>b, g</i>
	<i>Caranx senegallus</i> Cuvier, 1833	<i>b, g, h</i>
	<i>Chloroscombrus chrysurus</i> (Linnaeus, 1766)	<i>a, c, d, e, f</i>
	<i>Decapterus macarellus</i> (Cuvier, 1833)	<i>a, h</i>
	<i>Decapterus punctatus</i> (Cuvier, 1829)	<i>a, d, e</i>
	<i>Lichia amia</i> (Linnaeus, 1758)	<i>a, b, f, g</i>
	<i>Selene dorsalis</i> (Gill, 1863)	<i>g</i>
	<i>Trachinotus maxillosus</i> (Cuvier, 1832)	<i>f</i>
	<i>Trachinotus ovatus</i> (Linnaeus, 1758)	<i>b, g</i>
<i>Trachinotus teraia</i> (Cuvier, 1832)	<i>b, f, g, h</i>	
CARCHARHINIDAE	<i>Galeocerdo cuvier</i> (Péron & Lesueur, 1822)	<i>e</i>
CICHLIDAE	<i>Coptodon guineensis</i> (Günther, 1862)	<i>a, c, d, e, h</i>
	<i>Hemichromis elongatus</i> (Guichenot, 1861)	<i>b, f, h</i>
	<i>Pelmatolapia cabrae</i> (Boulenger, 1899)	<i>b, f, g</i>
	<i>Sarotherodon melanotheron</i> Rüppell, 1852	<i>f, h</i>
	<i>Sarotherodon nigripinnis</i> (Guichenot, 1861)	<i>g</i>
CLAROTEIDAE	<i>Chrysichthys auratus</i> (Geoffroy St. Hilaire, 1809)	<i>f</i>
	<i>Chrysichthys nigrodigitatus</i> (Lacepède, 1803)	<i>a, c, d, e, h</i>
CLUPEIDAE	<i>Ethmalosa fimbriata</i> (Bowdich, 1825)	<i>h</i>
	<i>Odaxothrissa ansorgii</i> (Boulenger, 1910)	<i>b, h</i>
	<i>Pellonula leonensis</i> Boulenger, 1916	<i>f, h</i>
	<i>Pellonula vorax</i> Günther, 1868	<i>g, h</i>
	<i>Sardinella aurita</i> (Valenciennes, 1847)	<i>a, b, f, g</i>
	<i>Sardinella maderensis</i> (Lowe, 1839)	<i>b, f, g, h</i>
CONGRIDAE	<i>Bathyyroconger vicinus</i> (Vaillant, 1888)	<i>b, g</i>
CYNOGLOSSIDAE	<i>Cynoglossus browni</i> Chabanaud, 1949	<i>a, b, f, g, h</i>
	<i>Cynoglossus monodi</i> Chabanaud, 1949	<i>h</i>
	<i>Cynoglossus senegalensis</i> (Kaup, 1858)	<i>f, g, h</i>
CYPRINIDAE	<i>Enteromius holotaenia</i> (Boulenger, 1904)	<i>c, d, e, h</i>
DASYATIDAE	<i>Fontitrygon margarita</i> (Linnaeus, 1758)	<i>b, f, h</i>
	<i>Fontitrygon margaritella</i> (Compagno & Roberts, 1984)	<i>b, h</i>

	<i>Fontitrygon ukpam</i> (Smith, 1863)	<i>a, b, e, f, h</i>
DINOPERCIDAE	<i>Centrarchops atlanticus</i> (Reichenow 1877)	<i>g</i>
ELEOTRIDAE	<i>Bostrychus africanus</i> (Steindachner, 1879)	<i>g</i>
	<i>Eleotris daganensis</i> (Steindachner, 1870)	<i>a, b, h</i>
	<i>Eleotris senegalensis</i> (Steindachner, 1870)	<i>h</i>
	<i>Kribia kribensis</i> (Boulenger, 1907)	<i>b, d, f</i>
ELOPIDAE	<i>Elops lacerta</i> (Valenciennes, 1847)	<i>b, g</i>
	<i>Elops senegalensis</i> (Regan, 1909)	<i>a, b, c</i>
EPHIPPIDAE	<i>Chaetodipterus lippei</i> (Steindachner, 1895)	<i>g, h</i>
GERREIDAE	<i>Eucinostomus melanopterus</i> (Bleeker, 1863)	<i>f, g, h</i>
	<i>Gerres nigri</i> Günther, 1859	<i>a, b, e, h</i>
GLAUCOSTEGIDAE	<i>Glaucostegus cemiculus</i> (Geoffroy St. Hilaire, 1817)	<i>c, d, e</i>
GOBIIDAE	<i>Awaous lateristriga</i> (Duméril, 1861)	<i>b, f, g</i>
	<i>Bathygobius soporator</i> (Valenciennes, 1837)	<i>g</i>
	<i>Nematogobius maindroni</i> (Sauvage, 1880)	<i>g, h</i>
	<i>Periophthalmus barbarus</i> (Linnaeus, 1766)	<i>b, h</i>
	<i>Porogobius schlegelii</i> (Günther, 1861)	<i>h</i>
HAEMULIDAE	<i>Plectorhinchus macrolepis</i> (Boulenger, 1899)	<i>b, f, g, h</i>
	<i>Pomadasys jubelini</i> (Cuvier, 1830)	<i>g, h</i>
	<i>Pomadasys perotai</i> (Cuvier, 1830)	<i>b, g, h</i>
	<i>Pomadasys rogerii</i> (Cuvier, 1830)	<i>g</i>
	<i>Pomadasys suillus</i> (Valenciennes, 1833)	<i>b, f, g</i>
HEMIGALEIDAE	<i>Paragaleus pectoralis</i> (Garman, 1906)	<i>a, f, g</i>
LOBOTIDAE	<i>Lobotes surinamensis</i> (Bloch, 1790)	<i>g</i>
LUTJANIDAE	<i>Lutjanus agennes</i> (Bleeker, 1863)	<i>g</i>
	<i>Lutjanus dentatus</i> (Duméril, 1861)	<i>b, c, e, f, g, h</i>
	<i>Lutjanus endecacanthus</i> (Bleeker, 1863)	<i>a, b, e, f, g, h</i>
	<i>Lutjanus fulgens</i> (Valenciennes, 1830)	<i>f</i>
	<i>Lutjanus gorensis</i> (Valenciennes, 1830)	<i>h</i>
MEGALOPIDAE	<i>Megalops atlanticus</i> (Valenciennes, 1847)	<i>a, b, f, g</i>
MONODACTYLIDAE	<i>Monodactylus sebae</i> (Cuvier, 1829)	<i>b, f, g, h</i>
MUGILIDAE	<i>Mugil bananensis</i> (Pellegrin, 1927)	<i>a, b, c, d, e</i>
	<i>Mugil cephalus</i> Linnaeus, 1758	<i>a, b, c, d, e, f, g, h</i>
	<i>Mugil curema</i> (Valenciennes, 1836)	<i>b, f</i>
	<i>Neochelon falcipinnis</i> (Valenciennes, 1836)	<i>h</i>
	<i>Parachelon grandisquamis</i> (Valenciennes, 1836)	<i>h</i>
MURAENIDAE	<i>Gymnothorax afer</i> (Bloch, 1795)	<i>h</i>
OPHICHTHIDAE	<i>Myrichthys pardalis</i> (Valenciennes, 1839)	<i>g, h</i>
PARALICHTHYIDAE	<i>Citharichthys stampflii</i> (Steindachner, 1894)	<i>c, d, e, h</i>
	<i>Syacium guineensis</i> (Bleeker, 1862)	<i>h</i>
POECILIIDAE	<i>Aplocheilichthys spilauchen</i> (Duméril, 1861)	<i>f, h</i>
POLYNEMIDAE	<i>Galeoides decadactylus</i> (Bloch, 1795)	<i>h</i>
	<i>Pentanemus quinquarius</i> (Linnaeus, 1758)	<i>b, f, g, h</i>
	<i>Polydactylus quadrifilis</i> (Cuvier, 1829)	<i>b, f, g, h</i>
PRISTIGASTERIDAE	<i>Ilisha africana</i> (Bloch, 1795)	<i>a, b, c, e, f, g, h</i>
PSETTODIDAE	<i>Psettodes belcheri</i> (Bennett, 1831)	<i>b</i>
	<i>Psettodes bennettii</i> Steindachner, 1870	<i>b, f, h</i>
RAJIDAE	<i>Raja miraletus</i> (Linnaeus, 1758)	<i>b</i>

RHINOBATIDAE	<i>Rhinobatos albomaculatus</i> (Norman, 1930)	<i>b</i>
	<i>Rhinobatos rhinobatos</i> (Linnaeus, 1758)	<i>b</i>
SCARIDAE	<i>Scarus hoefleri</i> (Steindachner, 1881)	<i>g</i>
SCIAENIDAE	<i>Pseudolithus elongatus</i> (Bowdich, 1825)	<i>f, g, h</i>
	<i>Pseudolithus senegalensis</i> (Valenciennes, 1833)	<i>b, h</i>
	<i>Pseudolithus senegallus</i> (Cuvier, 1830)	<i>h</i>
	<i>Pseudolithus typus</i> (Bleeker, 1863)	<i>b, g</i>
	<i>Umbrina canariensis</i> (Valenciennes, 1843)	<i>b, g</i>
	<i>Umbrina ronchus</i> Valenciennes, 1843	<i>g</i>
SCOMBRIDAE	<i>Orcynopsis unicolor</i> (Geoffroy St. Hilaire, 1817)	<i>a, d, f</i>
	<i>Scomberomorus tritor</i> (Cuvier, 1832)	<i>g</i>
SCYLORHINIDAE	<i>Scyliorhinus cervigoni</i> (Maurin & Bonnet, 1970)	<i>b</i>
SERRANIDAE	<i>Cephalopholis nigri</i> (Günther, 1859)	<i>a, b, f</i>
	<i>Cephalopholis taeniops</i> (Valenciennes, 1828)	<i>f, h</i>
	<i>Epinephelus aeneus</i> (Geoffroy St. Hilaire, 1817)	<i>f, h</i>
	<i>Epinephelus itajara</i> (Lichtenstein, 1822)	<i>b</i>
SPARIDAE	<i>Dentex congoensis</i> (Poll, 1954)	<i>a</i>
	<i>Pagellus bellottii</i> Steindachner, 1882	<i>c, e</i>
	<i>Pagrus auriga</i> (Valenciennes, 1843)	<i>a, b, f, g</i>
	<i>Pagrus caeruleostictus</i> (Valenciennes, 1830)	<i>b, f, g</i>
SPHYRAENIDAE	<i>Sphyraena afra</i> (Peters, 1844)	<i>a, b, f, g, h</i>
	<i>Sphyraena barracuda</i> (Edwards, 1771)	<i>f, g, h</i>
	<i>Sphyraena guachancho</i> (Cuvier, 1829)	<i>b, f, g</i>
STROMATEIDAE	<i>Stromateus fiatola</i> Linnaeus, 1758	<i>g</i>
TRICHIURIDAE	<i>Trichiurus lepturus</i> (Linnaeus, 1758)	<i>g</i>

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- 777 a - Mbega, J.-D., Mve Beh, J.-H. 2012. Biodiversité et exploitation des peuplements piscicoles  
778 en prévision de la campagne d'acquisition sismique 2D on shore des Blocs E2 (Ntoun  
779 Cocobeach) & F3 (Kango) par la société ENI.
- 780 b- Mve Beh, J.-H., Eva M.-F. 2010. Contribution à l'étude écologique de la baie de la Mondah  
781 : caractérisation du peuplement piscicole.
- 782 c -Mve Beh, J.-H., 2012. Evaluation des peuplements ichtyologiques de la rivière Mbomo en  
783 perspective de l'aménagement d'une prise d'eau.
- 784 d - Mve Beh, J.-H., 2012. Biodiversité des peuplements ichtyologiques des rivières Nzémé,  
785 Assengo et Mbé en perspective du renforcement de la production d'eau potable.
- 786 e - Mve Beh, J.-H., 2013. Etude de la diversité ichtyologique de la rivière MEBA en  
787 perspective de l'aménagement d'une carrière de calcaire.
- 788 f - Van de Weghe, J.-P., 2005. Les Parcs Nationaux Du Gabon. Akanda et Pongara: Plages et  
789 Mangroves. Gabon Wildlife Conservation Society, Libreville, Gabon. 208 p.
- 790 g - Yendze, A.C, McClellan, C, Cardiec, F. 2016. Diagnostic de la pêche artisanale dans la zone  
791 du Cap Esterias et de Cocobeach.
- 792 h – Present study
- 793