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1 **Tidal effect on the dispersion of fecal pollution indicator bacteria and associated health**
2 **risks along the Kribi beaches (Southern Atlantic coast, Cameroon)**

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25 **Abstract**

26 Assessment of fecal contamination indicator bacteria concentrations on beaches are important
27 for health risk prevention and management. This study assessed temporal changes in bacterial
28 abundances as a function of tidal cycles and seasons along the Kribi beaches, Cameroon.
29 Overall, samples taken during low and high tides during the different seasons of the year
30 showed that the waters of Kribi beaches are exposed to fecal contamination due to the
31 presence of different concentrations of fecal coliforms (5-35 CFU/100 ml), total coliforms
32 (100-600 CFU/100 ml), *Escherichia coli* (0-15 CFU/100 ml), *Streptococcus feacalis* (50-700
33 CFU/100 ml), *Pseudomonas aeruginosa* (300-7200 CFU/100 ml), *Vibrio cholerea* (5-250
34 CFU/100 ml), *Vibrio parahemoliticus* (0-115 CFU/100 ml), and Aerobic Mesophilic
35 Heterotrophic Bacteria (99-875 CFU/100 ml). Regardless of bacterial strain and sampling site,
36 cell abundances were significant at low tides and during rainy seasons. At each sampling
37 station (Mpalla, Ngoyè and Mboamanga), depending on the seasons and tidal cycles,
38 significant correlations were recorded between the abundances of some bacterial strains and
39 some environmental variables ($P < 0.05$). The presence and high abundance of these
40 potentially pathogenic bacterial strains in the waters of Kribi beaches constitute a real public
41 health threat for swimmers. The limitation of this microbiological pollution requires the
42 implementation of an efficient collection and treatment plan for solid and liquid waste
43 (sanitary wastewater) in the city of Kribi.

44 **Keywords:** fecal pollution; health risks; Kribi beaches; tidal cycles; solid and liquid waste
45 management

49 **Introduction**

1
2
3 50 Microbial pollution of coastal recreation areas is a serious ecological and public health
4
5 51 problem (Xue et al., 2022; Manini et al., 2022). Runoff, from urban, domestic, and industrial
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7 52 wastes, can support intense microplankton growth and proliferation of pathogenic
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9 53 microorganisms (Basili et al., 2021). To prevent swimming-related infectious diseases, it is
10
11 54 therefore recommended that beach water quality be monitored by quantifying total and fecal
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13 55 coliforms and enterococci (Kongprajug et al., 2021; Makkaew et al., 2021). Epidemiological
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15 56 studies of different aquatic environments have shown a relationship between coliform
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17 57 quantification and the frequency of infectious disease (Martínez et al., 2007; WHO, 2021).
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23 58 Fecal contamination is one of many forms of contamination that can affect water ecosystems
24
25 59 (Manzeu Tonleu et al., 2021). The presence of pathogenic microorganisms in fecal matter
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27 60 such as viruses, bacteria, and parasitic protists makes consumption or contact with
28
29 61 contaminated water risky for human health. Fecal contamination has an economic impact, as
30
31 62 it can affect the development of recreational and tourist activities (Martínez et al., 2007).
32
33 63 Many potential sources of fecal contamination can affect water quality. Human sources are
34
35 64 mainly from discharges through sanitary sewers, treated or not, discharged into waterways.
36
37 65 Animal sources include livestock operations and manure spreading. Heavy rainfall can then
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39 66 cause runoff to streams and migration to groundwater (Saingam et al., 2020). Animal
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41 67 contamination can also come from wildlife and urban wildlife, such as that caused by
42
43 68 raccoons. In developing countries, waterborne outbreaks attributed to fecal contamination are
44
45 69 very common (Ashbolt, 2004). They are partly explained by two important factors; a lack of
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47 70 appropriate infrastructure and drinking water purification treatment as well as a lack of
48
49 71 infrastructure for sanitary wastewater treatment and disposal (Yahya et al., 2017; Edge et al.,
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51 72 2021).
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73 Swimming in water of poor microbiological quality thus poses health risks and can lead to
74 several infections, mainly gastroenteritis, more or less severe depending on the germs
75 involved, ear infections and dermatitis (Manezeu Tonleu et al., 2021). In rare cases,
76 contaminated water can also lead to more serious infectious diseases such as typhoid, cholera,
77 etc. (Nimnoi and Pongsilp, 2020). Some elements of the environment can also act as a
78 "vector" of contamination from water to humans, notably shellfish, which are particularly
79 sensitive to pollution due to their physiology. Indeed, they are microphagous filter-feeding
80 organisms, which feed on assimilable particles from the surrounding environment,
81 phytoplankton and bacteria and concentrate them in their digestive system (Yahya et al.,
82 2017; Edge et al., 2021).

83 In sub-Saharan Africa in general and Cameroon in particular, data on microbiological
84 standards of beach waters are scarce (Leme Banock et al., 2014), yet these environments
85 constitute high contamination sites given their high frequency of use at all seasons of the year.
86 Moreover, very few studies have been conducted on the impact of beach water quality on the
87 health of the population. There is almost no data on the classification of Cameroonian beach
88 water in relation to the standards of the World Health Organization. There is a problem of
89 permanent fecal contamination and public health on Cameroonian beaches in general and
90 those of Kribi in particular. The main objective of this study was to evaluate the influence of
91 tides and seasons on the dissemination of enteric bacteria and its associated health risks along
92 the Kribi beaches, in the Southern Region of Cameroon. Specifically, it was necessary to
93 perform qualitative and quantitative analyses of some indicator bacteria of fecal
94 contamination on three beaches of Kribi (Mpalla, Ngoyè and Mboamanga), during high and
95 low tides and at different seasons of the year: Long Dry Season (LDS), Short Rainy Season
96 (SRS), Short Dry Season (SDS) and Long Rainy Season (LRS). In this study, the hypothesis

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97 that the spread of enteric bacteria along the Kribi beaches is influenced by the tidal cycle and
98 the seasons will be tested.

99 **1. Materials and methods**

100 ***1.1. Study area***

101 The study was conducted in 2021 year on three most frequented beaches of the city of Kribi,
102 in the Ocean Division, Cameroon southern Atlantic coast (Figure 1). This area is subject to a
103 Guinean-type equatorial climate, characterized by four seasons: LDS from December to
104 February, SRS from March to May, SDS from June to July and LRS from August to
105 November (Olivry 1986; Dzana 2011; Mama et al. 2018). Four sampling campaigns were
106 conducted: January (LDS), April (SRS), July (SDS) and October (LRS) respectively. At the
107 level of each beach, one sampling station was surveyed based on its accessibility and
108 frequentation. Station 1 is located at Mpalla beach (3°00'29"N - 0009°56'54.5"E) and
109 characterized by a gray sandy substrate. Station 2 is situated at Ngoyè (2°57'26.6"N -
110 0009°54'36.9"E), at 4 km from Mpalla, and characterized by a black sandy substrate. Located
111 at 9 km from Ngoyè, station 3 on Mboamanga beach (02°56'22.4"N - 0009°54'12.3"), is
112 characterized by the sandy clay gray substrate.

113 ***1.2. Measurement of abiotic parameters***

114 Physicochemical parameters were analyzed according to Rodier et al. (2009) and APHA
115 (2017) standard methods. At each campaign and each sampling station, eight physico-
116 chemical parameters were measured *in situ*, in triplicate during each tide period (low and high
117 tide), using a hand-held multiparameter (HANNA/HI9829). These variables include pH (CU),
118 Salinity (PSU), Temperature (°C), Dissolved Oxygen (mg/l), Suspended Solids (mg/l),
119 Turbidity (NTU), Total Dissolved Solids (mg/l) and Electrical Conductivity (mS/cm).
120 Additional, water depth and current velocity were also measured during low and high tides.

121 **1.3. Bacteriological analysis**

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3 122 At each station, water samples were collected at high and low tide, in 1000 ml sterile
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5 123 polyethylene bottles, bacteriological analyses were focused on the isolation and enumeration
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8 124 of eight strains. The bacteria were isolated by surface plating in 90-mm diameter petri dishes
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10 125 containing Endo culture media for fecal coliforms, total coliforms and *Echerichia coli*, Bile
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12 126 Esculin Azide (BEA) for *Streptococcus feacalis*, Cetrimide agar for *Pseudomonas*
13
14 127 *aeruginosa*, TCBS agar for *Vibrio* spp and Plate Count Agar (PCA) for mesophilic aerobic
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17 128 heterotrophic bacteria. The number of colony forming units (CFU) is expressed in CFU/100
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20 129 ml of water according to the formula (Ajeegah et al., 2010):

$$23 \quad 130 \quad Ab = (Nc/Vw) \times 100$$

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26 131 Ab = abundance (CFU/100 ml), Nc = number of colonies counted on the petri dish, Vw =
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28 132 volume of water analyzed (ml).

32 133 **1.4. Data analysis**

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35 134 The SPSS software version 16.0 allowed us to perform correlation tests. P values were used to
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37 135 assess the significance of the correlation between abiotic and biotic parameters. The safety
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40 136 threshold was 5% ($P < 0.05$).

43 137 **2. Results**

46 138 **2.1. Abiotic variables**

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49 139 At the different surveyed site, the minimum water depth (0.30 m) was recorded at low tide
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51 140 during the SDS at Mpalla and the LDS at Mboamanga. As for the depth (2.07 m), was
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53 141 recorded at high tide at Ngoyè, during the LRS (Table I). The maximum tidal range (1.62 m)
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56 142 was obtained during the LRS at Ngoyè. On the other hand, the minimum tidal range (1.03 m),
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59 143 was obtained during the LDS at Mboamanga. Overall, at the different sampling points, the

144 current velocity was higher at low tide than at high tide, during all seasons of the year (LDR,
145 SRS, SDR and LRS). The lowest current was recorded during SDS at high tide, on Ngoyè
146 beach with a value of 0.90 m/s (Table I).

147 During the SRS, whether at high or low tide, the waters of the surveyed beaches were strongly
148 basic with a maximum pH value of 8.81 CU recorded at Mboamanga. The lowest pH value
149 (6.89 CU) was recorded at Mboamanga during high tide, during the LDS (Figure 2A). Salinity
150 values were slightly higher at low tide than at high tide. Overall, salinity values showed a
151 decreasing trend from the dry seasons (LDS, SDS) to the rainy seasons (SRS, LRS). The
152 minimum salinity (31.01 PSU) was recorded during the LRS, at high tide at Ngoyè and the
153 maximum value (35.77 PSU) during the LDS, at low tide at Mboamanga (Figure 2B).

154 During high tide, water temperature ranged from 26.16°C during LRS at Ngoyè to 31.75°C
155 during LDS at Mboamanga. At low tide, the water temperature ranged from 27.29 °C at LRS
156 at Ngoyè to 32.44 °C at LDS at Mpalla (Figure 2C). At all stations, the warmest water was
157 recorded at low tide, specifically during dry periods (LDS, SDS). Regardless of the tidal
158 cycle, Kribi beach waters were significantly more oxygenated during the rainy seasons (LRS,
159 SRS) than during the dry seasons (LDS, SDS). The minimum value (2.99 mg/l) was recorded
160 at Ngoyè at low tide during the SDS. On the other hand, the maximum value (5.12 mg/l) was
161 obtained at high tide at Mpalla during the LRS (Figure 2D).

162 The waters of the Kribi beaches contain high amounts of suspended solids. However, these
163 values were more significant at high tide than at low tide. The maximum value (131 mg/l) was
164 obtained at Mboamanga at high tide and during the SRS (Figure 2E). The high amount of
165 suspended solids contained in the waters of the Kribi beaches would justify its high turbidity.
166 Indeed, regardless of the tidal cycle, maximum turbidity values were recorded during the
167 rainy seasons (SRS, LRS) at all surveyed sites (Figure 2F). Total Dissolved Solids evolved

168 from 412 mg/l (in LDS) to 716 mg/l (in LRS) during high tide and from 375 mg/l (in LDS) to
169 636 mg/l (in LRS) during low tide (Figure 2G). Indeed, across all three beaches surveyed, the
170 waters of Mpalla were lower in inorganic salts and some small amounts of dissolved organic
171 matter. Regardless of the tidal cycle, electrical conductivity values varied very little from one
172 season to the next. However, it was noted that the waters of the Kribi beaches were less
173 loaded with ions, mineral salts and dissolved trace elements during the dry seasons (LDS,
174 SDS) than during the rainy seasons (SRS, LRS) (Figure 2H).

175 **2.2. Bacterial distribution and abundance**

176 Bacteriological analyses have revealed an abundant diversity of bacterial strains in the waters
177 of Kribi beaches: faecal coliforms, total coliforms, *Escherichia coli*, *Streptococcus faecalis*,
178 *Pseudomonas aeruginosa*, *Vibrio cholerea*, *Vibrio parahemoliticus*, and Aerobic Mesophilic
179 Heterotrophic Bacteria. These bacteria are found exclusively in human and animal feces and
180 are potentially pathogenic when their load exceeds a certain threshold in the environment.
181 Their pathogenicity is either specific (they cause specific pathologies) or opportunistic (they
182 are only expressed on weakened individuals). It should be noted that the presence of *Vibrio*
183 *cholerea* and *V. parahemoliticus* on the water of the Kibi beaches indicates a high health risk.
184 Overall, the high concentrations of bacteria found in this study were recorded during low tides
185 and mainly during the rainy seasons (SRS, LRS) (Figures 3A-H). Fecal coliforms were the
186 least abundant strains (5-35 CFU/100 ml); in contrast to *Pseudomonas aeruginosa* whose
187 maximum concentrations reached 2700 CFU/100 ml during low tide at Mpalla during the
188 SRS.

189 Different groups of bacteria are used as indicators of fecal contamination in different
190 countries and jurisdictions. Total and fecal coliforms have been the main indicators of fecal
191 contamination for a long time, but nowadays *Escherichia coli* and intestinal enterococci are

192 recognized as more appropriate and proposed to replace coliforms in some microbiological
193 water quality standards. However, it is important to understand the potential and limitations of
194 these different indicators in tropical bathing waters, particularly those of the Kribi beaches.

195 **2.3 Correlation between abiotic and biotic variables**

196 On all the beaches surveyed, significant correlations were found between certain abiotic and
197 biotic parameters, exclusively at low tide and during the rainy seasons (SRS, LRS). Thus, at
198 Mpalla, a positive and significant correlation was observed, during SRS, between
199 *Streptococcus faecalis* and turbidity ($r = 0.713$, $P = 0.045$). At Ngoyè, significant positive
200 correlations were observed during the SRS between *Vibrio parahemoliticus* and dissolved
201 oxygen ($r = 0.628$, $P = 0.041$); between Aerobic Mesophilic Heterotrophic Bacteria and
202 suspended solids during the SRS ($r = 0.638$, $P = 0.033$). At Mboamanga, Total coliforms and
203 *Escherichia coli* were positively correlated during SRS with temperature ($r = 0.811$, $P = 0.045$
204 and $r = 0.732$, $P = 0.038$).

205 Comparison of the mean abundances of *Pseudomonas aeruginosa* at low tide, according to
206 the two main seasons (LDS+SDS and SRS+LRS) showed a significant difference at Ngoyè (P
207 = 0.048). At Mboamanga, under the same conditions, there was also a significant difference
208 between the means of Fecal coliform abundances ($P = 0.044$). On all the sites surveyed, these
209 comparison tests revealed no significant difference at high tide. Seasonal variations, tidal
210 cycles and environmental variables seem to have an influence on the dynamics of
211 microorganisms along the Kribi beaches.

212 **3. Discussion**

213 Although swimming is recreational activity that allows relaxation and physical exercise that is
214 beneficial to health, it thus present certain health risks, which are related to the swimming
215 activities, but especially to the physicochemical and microbiological quality of the water

216 (Basili et al., 2021). This study revealed several strains of potentially pathogenic enteric
217 bacteria in the waters of Kribi beaches, whose abundance varied from one season to another
218 and according to tidal cycles.

219 Indeed, microbiological pollution is one of the major problems facing coastal and marine
220 environments today (Dang and Lovell, 2016; Basili et al., 2021). This term refers to the
221 presence in these ecosystems of microbial germs, such as bacteria, viruses or parasites, some
222 of which may be pathogenic to humans or animals (Nimnoi and Pongsilp, 2020). While
223 marine and coastal ecosystems are the natural environment for some microorganisms, most of
224 the germs implicated in the microbiological contamination of the waters of Kribi beaches are
225 of human origin (Rodríguez et al., 2021). These are mainly enteric bacteria, i.e. from the
226 intestines of humans or warm-blooded animals and brought into the environment via their
227 excreta: discharges of treated and untreated sewage on land, ships, ballast water, livestock
228 effluents (animal feces), stormwater discharges, rainfall runoff and other diffuse sources
229 (Assako Assako et al., 2010; Manini et al., 2022).

230 Several causes would explain the arrival of fecal bacteria along the Kribi beaches. Human
231 contamination is mainly linked to a total absence of wastewater treatment systems in this city.
232 Indeed, the city of Kribi has no real wastewater and faecal sludge treatment system (Assako
233 Assako et al., 2010). The treatment plants are non-existent. Naturally, any absence or defect in
234 the collective sanitation system can lead to the discharge of raw water into the aquatic
235 environment, resulting in the introduction of microbial germs into the natural environment
236 (Basili et al., 2021; Rodríguez et al., 2021). Other activities on the Kribian coast could lead to
237 the input of enteric bacteria into the environment, in particular: recreational activities,
238 especially when the boats are inhabited and do not have a wastewater collection system. Fecal
239 pollution due to these activities is mainly located at marinas and fishing camps. Recreational

240 activities, including swimming, restaurants (contamination related to these activities is
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2 241 however "secondary" and their impact on coastal uses seems very low) (Weiskerger et al.,
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5 242 2019; WHO, 2021).

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8 243 Contamination of animal origin is essentially linked to agricultural activities in the watershed
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10 244 of the Nyong and Kienké rivers, which flow through the city of Kribi before emptying into the
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13 245 sea. These contaminants would come from the leaching of grazed surfaces and the movement
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15 246 of livestock, which during rainy episodes, drain the contaminants present in the soil towards
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17 247 these rivers that flow into the sea. Rainfall would therefore be one of the main factors in the
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20 248 dispersal of these enteric bacteria (Di Biase & Hanssen, 2021; Manini et al., 2022). These
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22 249 contaminations could also be due to industries, especially agri-food industries, if their
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25 250 effluents are not properly treated, or to wildlife, especially poultry (Yahya et al., 2017; Edge
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27 251 et al., 2021). Indeed, the lack of a collection and treatment system for solid and liquid waste in
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30 252 the city of Kribi is conducive to the deposition of sediment, which would promote the
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32 253 development of microorganisms that will be evacuated to the beaches during rainy episodes.
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35 254 This would explain the high abundance of bacterial strains found along the Kribi beaches
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37 255 during the rainy seasons (SRS, LRS).

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40 256 In the city of Kribi, wastewater disposal is generally done individually. Household wastewater
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43 257 is discharged into the environment. Apart from a few homes that have modern cesspits (about
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45 258 15%), most people pour their wastewater into the yard or into poorly equipped traditional
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48 259 latrines in the open. The flatness of the terrain and the presence of multiple geomorphological
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50 260 depressions mean that domestic wastewater discharged into nature, obviously without any
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52 261 treatment, creates numerous stagnation points where a host of pathogenic germs, parasites and
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55 262 infectious disease vectors develop and are washed ashore during SRS and LRS (Assako
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57 263 Assako et al., 2010). In the case of hotels, which are generally located on the coast, their

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264 septic tanks are emptied by private drainage companies. These waste are generally transported
265 and dumped, without any prior treatment, upstream of the Nyong and Kienké rivers, which
266 flow into the sea.

267 Ballast water is considered one of the most worrisome vectors of species introduce worldwide
268 (Bradie et al., 2022). Since the deep sea port of Kribi became operational, several hundred
269 taxa would be contained in the ballast water of ships that dock there. These are mainly
270 planktonic microorganisms, but also pathogenic parasites, including enteric bacteria.

271 When microorganisms, favored by rainfall, are drained onto the coastal zone, their abundance
272 and diffusion rate would depend on tidal range, physicochemical variables, and
273 hydrodynamics, among other things (Di Biase and Hanssen, 2021). Tides generate and
274 influence ocean currents (Madani et al., 2020). In turn, these currents directly and indirectly
275 affect the movement of aquatic fauna (seedlings, fish) and the dispersion of microbes. Like
276 the tide, winds, underwater topography, climatic conditions, and prey behavior influence the
277 dispersal of microorganisms (Ferrarin et al., 2021, Kraus et al., 2022). Influenced in turn by
278 tidal cycles and seasons, physico-chemical variables would have an impact on the survival
279 and abundance of bacteria along the Kribi beaches. Indeed, the dilution that occurs
280 immediately after the discharge is favored by the mixing of waters: currents, turbulence and
281 tidal action. It is estimated that 90-99% of sewage bacteria are destroyed after 48 hours of
282 suspension in seawater and that their numbers decrease with distance much faster than would
283 be expected from simple dilution (Kraus et al., 2022). Direct or indirect sedimentation
284 determines the momentary disappearance of bacteria. This disappearance may be temporary,
285 as there may be resuspension of sediment and bacteria. This process is very effective in calm
286 waters, but is reduced by the turbulence of beach waters. Some studies have shown that fecal
287 coliforms in seawater are very sensitive to sunlight (Chedad and Assobhei, 2007). This can be

288 explained by the bactericidal effect of the UV fraction of solar radiation on the cell, inducing
289 damage by release of peroxide ions that act on the cell making it permeable to inorganic salts,
290 which then varies its osmotic pressure. This would explain the low bacterial abundance
291 recorded on the Kribi beaches during the dry seasons (SDS, LDS). Generally, low
292 temperatures favor the survival of bacteria in the marine environment by limiting their
293 energetic expenditure by decreasing the metabolic activities of bacteria (Chedad and
294 Assobhei, 2007). This explains the high concentration of bacteria observed during LRS and
295 SRS. High turbidity of the water would limit the penetration of UV rays into the water and
296 also contribute to reduce the efficiency of UV rays towards bacterial cells. This turbidity is
297 due to terrigenous inputs on one hand and the other hand to resuspension by waves and
298 current to resuspension by waves and currents, as well as the contribution of organic particles.
299 Work has shown that the survival of fecal coliforms was influenced by the pH of the
300 incubation medium. Indeed, basic pH levels would result in a significant decrease in fecal
301 coliform survival (Chedad and Assobhei, 2007). Salinity is also a very important stress factor
302 that fecal pollution bacteria undergo when they arrive in the marine environment (Hughes,
303 2003), where the bacteria must re-establish the osmotic equilibrium between the external
304 environment and its cytoplasm. This re-establishment involves complex mechanisms that
305 involve increasing the concentration of certain solutes (osmo-regulators) in the bacteria. Thus,
306 strong variations in salinity from one environment to another tend to prevent the habituation
307 of allochthonous bacteria to their new environment, which would lead to a decrease in their
308 numbers. Authors have also pointed out that the presence of organic particles allows
309 microorganisms to fight more effectively against salt stress (Pommepuy et al., 1991).

310 Enteric bacteria introduced into the marine environment can affect swimming water quality
311 and cause health impacts, which can lead to the closure of affected beaches if contamination
312 is significant and persistent (Bonadonna et al., 2019; Manezeu Tonleu et al., 2021). Enteric

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313 diseases are among the most common infections in the world and affect the poorest and most
314 disadvantaged communities (WHO, 2006). They are transmitted by strains present in human
315 excreta, which contaminate soils where sanitation conditions are inadequate. Swimming in
316 water of poor microbiological quality thus presents health risks and can lead to infections,
317 mainly gastroenteritis, more or less severe depending on the germs involved, ear infections
318 and dermatitis (WHO, 2006; Bonadonna et al., 2019; Manezeu Tonleu et al., 2021). In rare
319 cases, contaminated water can also lead to more serious infectious diseases such as typhoid,
320 cholera, etc (WHO, 1994). On the Kribi beaches, bathers would be more exposed during low
321 tides (less dilution) and during the rainy seasons (leaching and drainage of wastewater to the
322 coastal zone).

323 **Conclusion**

324 The main objective of this study was to evaluate the influence of tidal cycles and seasons on
325 the dispersion of enteric bacteria in the waters of Kribi beaches. It was found that the waters
326 of the beaches surveyed concentrated large quantities of bacteria indicative of fecal
327 contamination. These bacterial strains, potentially pathogenic, originating mainly from
328 untreated solid and liquid waste from the city of Kribi, were significantly more abundant
329 during low tides and the rainy season. Despite the many benefits of swimming in the waters of
330 Kribi beaches, it is not without risks to human health. Indeed, it is possible to develop
331 infections such as enteric diseases. More serious complications such as hemolytic uremic
332 syndrome can sometimes occur. Monitoring of fecal contamination indicators on Kribi
333 beaches would provide useful information on changes in water quality that may occur and
334 provide a measure for public health decision making. However, water quality monitoring
335 results should not be the sole measure of whether an area is suitable for recreational activities.
336 Routine monitoring for *Escherichia coli* or enterococci should be an integral part of a

1 337 preventive risk management approach to protect the health of recreational water users. It
2 338 should be noted that today, the level of microbiological standards for swimming waters is
3
4 339 generally established on the basis of epidemiological studies conducted only in temperate
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6
7 340 regions and whose results are probably not directly transposable to tropical regions; it seems
8
9 341 important today to launch specific epidemiological studies in tropical regions to ensure the
10
11 342 relevance of microbiological quality standards. Better management of the health risk
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13 343 associated with the water on the Kribi beaches requires the continuation of epidemiological
14
15 344 studies in order to better understand the relationship between the presence of indicators and
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17 345 the occurrence of diseases, but also requires further study of the ecology indicator and
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19 346 pathogenic germs in the natural aquatic environment.
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25 347 **Declaration of Competing Interest**

26
27
28 348 The authors declare that they have no known competing financial interests or personal
29
30 349 relationships that could have appeared to influence the work reported in this paper.
31
32

33 350 **Credit authorship contribution statement**

34
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36 351 **Paul Alain Nana ; Rodrigue Ebonji Seth ; Noël Arlette Ndjussi Tamko ; Victorin**
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38 352 **Rodrigue Onambélé Ossomba ; Claire Stéphane Metsopkeng:** Conceptualization,
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40 353 Methodology, Writing – original draft. **Geneviève Bricheux ; Moïse Nola ; Télésphore**
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6 498 **List of figures**

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9 499 **Figure 1** : Location map showing sampling points

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12 500 **Figure 2** : Physico-chemical variables according to tidal cycles and seasons. **A** : pH (CU), **B** :

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14 501 Salinity (PSU), **C** : Temperature (°C), **D** : Dissolved Oxygen (mg/l), **E** : Suspended

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16 502 Solids (mg/l), **F** : Turbidity (NTU), **G** : Total Dissolved Solids (mg/l), **H** : Electrical

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18 503 Conductivity (mS/cm)

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22 504 **Figure 3** : Bacterial abundances according to tidal cycles and seasons. **A** : Coliformes fécaux,

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25 505 **B** : Coliformes totaux, **C** : *Escherichia coli*, **D** : *Streptococcus feacalis*, **E** :

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28 506 *Pseudomonas aeruginosa*, **F** : *Vibrio cholerea*, **G** : *Vibrio parahemoliticus*, **H** :

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31 507 Mesophilic Aerobic Heterotrophic Bacteria

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9 520 **Table I** : Some hydrodynamic characteristics of the surveyed sites

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	Mpalla				Ngoyè				Mboamanga			
	LDS	SRS	SDS	LRS	LDS	SRS	SDS	LRS	LDS	SRS	SDS	LRS
Water depth at low tide (m)	0.37	0.43	0.30	0.47	0.35	0.41	0.40	0.45	0.30	0.39	0.31	0.48
Water depth at high tide (m)	1.45	1.97	1.80	2.02	1.56	1.99	1.85	2.07	1.33	1.69	1.60	2.01
Marnage (m)	1.08	1.54	1.50	1.55	1.21	1.58	1.45	1.62	1.03	1.30	1.30	1.53
Wave current speed at low tide (m/s)	2.10	2.02	2.02	1.88	2.05	1.89	1.99	1.87	2.11	2.10	2.09	1.88
Wave current speed at high tide (m/s)	1.31	1.23	1.21	1.11	1.41	1.01	0.90	1.12	0.99	1.14	1.35	1.02

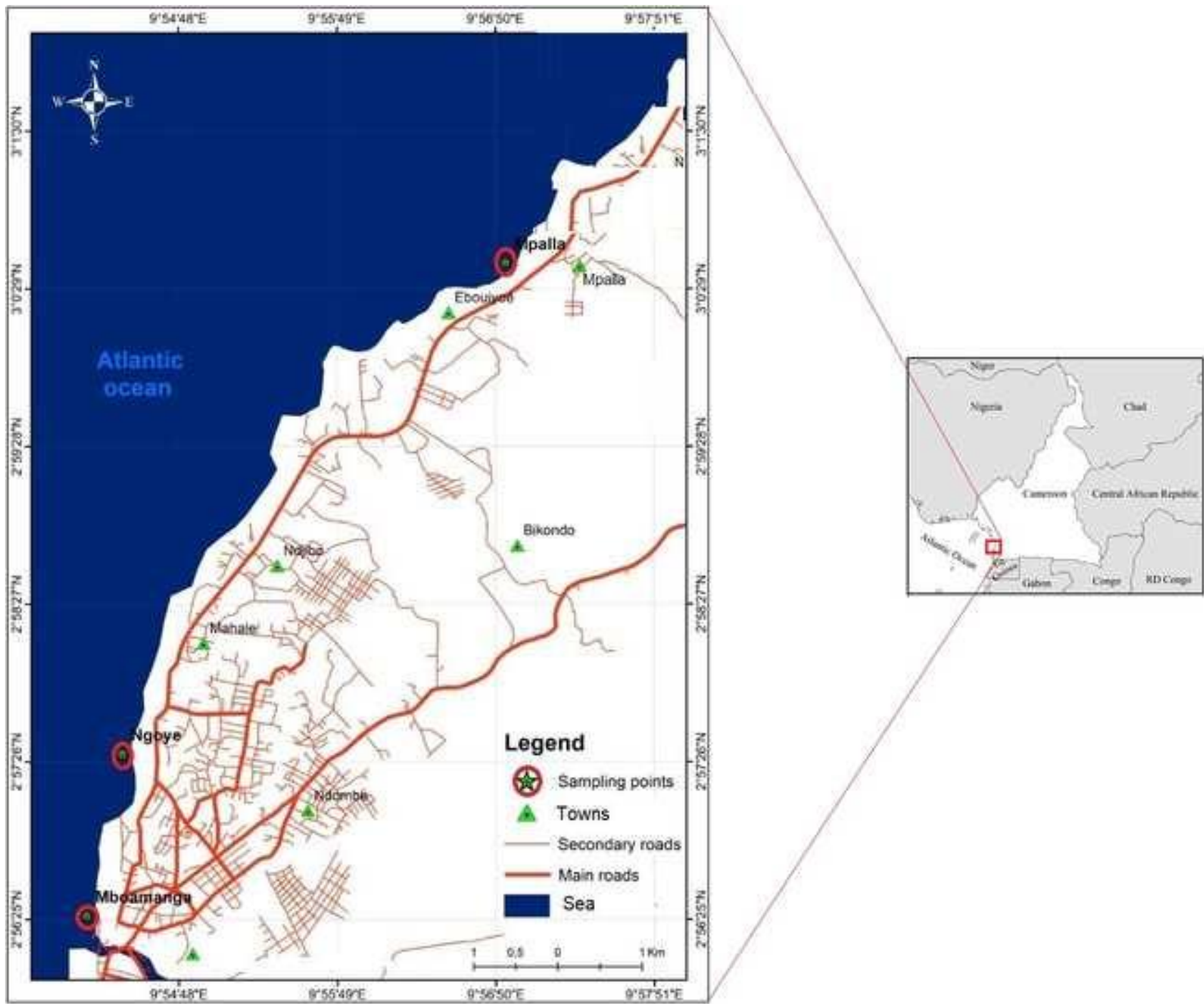
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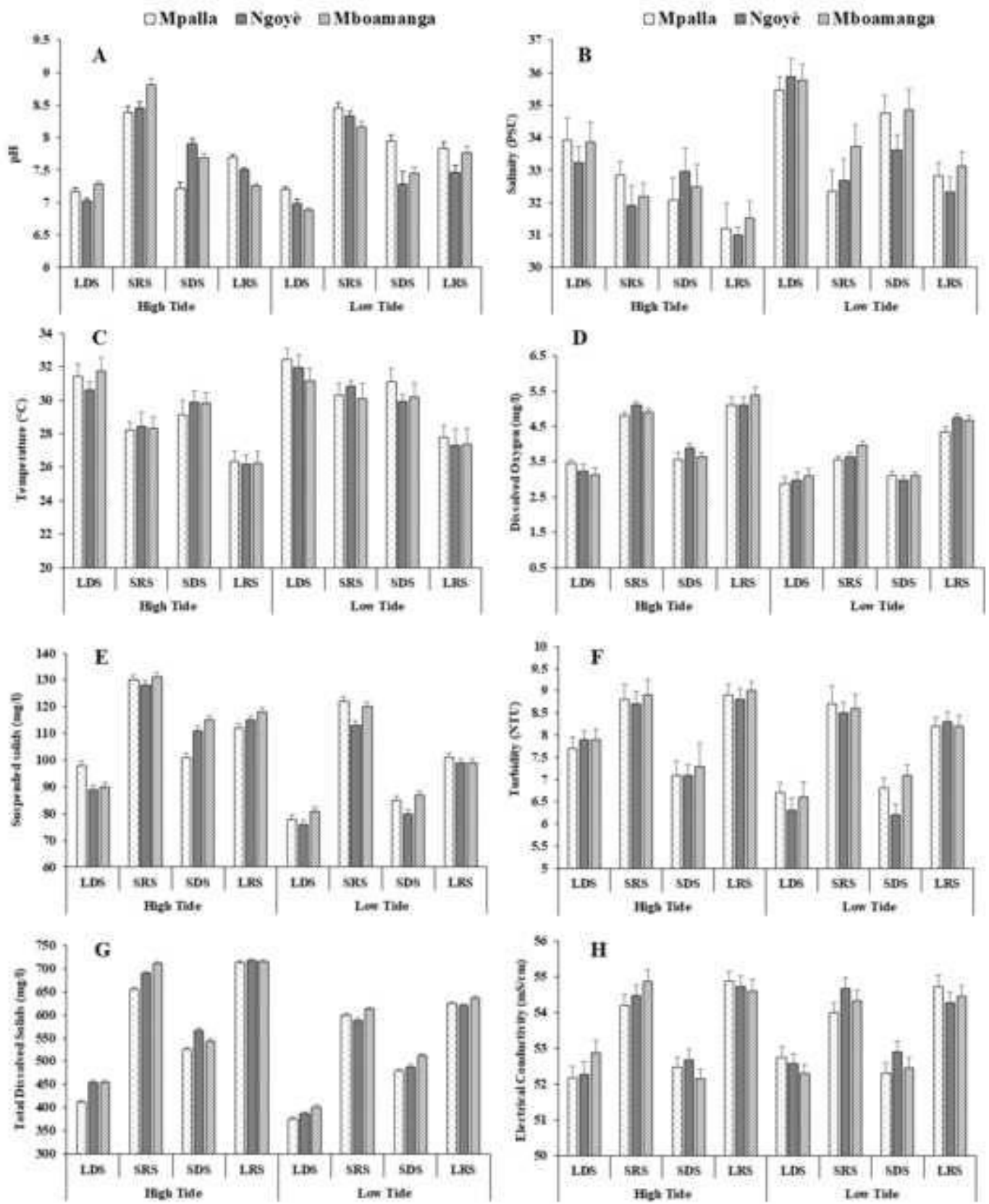
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