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Kinetics of metal and metalloid concentrations in holopelagic Sargassum reaching coastal environments

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1 **Title: Kinetics of metals and metalloid concentrations in holopelagic**
2 *Sargassum* reaching coastal environments.

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4
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23
24 **Running title:** Coastal environments *Sargassum* metals and metalloid concentrations

25
26 **Abstract:**

27 Since 2011, the Caribbean Islands have experienced unprecedented stranding of a pelagic
28 brown macroalgae *Sargassum* inducing damages for coastal ecosystems and economy. This
29 study measures the kinetics of metal trace elements (MTE) in *Sargassum* reaching different
30 coastal environments. In July 2021, over a period of 25 days, fixed experimental floating cages
31 containing the three *Sargassum* morphotypes (*S. fluitans* III and *S. natans* I and VIII) were
32 placed in three different coastal habitats (coral reef, seagrass and mangrove) in Guadeloupe

33 (French West Indies). Evolution of biomasses and their total phenolic content of *Sargassum*
34 reveals that environmental conditions of caging were stressful and end up to the death of algae.
35 Concentrations of 19 metal(loid)s trace elements were analyzed and three shapes of kinetics
36 were identified with the MTE that either concentrate, depurate or remains stable. In the
37 mangrove, evolution of MTE were more rapid than the two other habitats a decrease of the As
38 between 70 and 50 $\mu\text{g.g}^{-1}$ in the mangrove. *Sargassum natans* I presented a different metal
39 composition than the two other morphotypes, with higher contents of As and Zn. All *Sargassum*
40 morphotype are rapidly releasing the metal(oid)s Arsenic (As) when they arrive in studied
41 coastal habitats. In order to avoid the transfer of As from *Sargassum* to coastal environments,
42 *Sargassum* stranding should be avoided and their valorization must take into account their As
43 contents.

44 **Keywords (7 words):** Arsenic; *Sargassum*; coral reef; seagrass; mangrove; Caribbean;
45 metals.

46

47

48 1 Introduction

49

50 The *Sargassum* genus includes more than 350 species, constituting one of the most diverse
51 genera of brown macroalgae (Guiry and Guiry, 2022). Among this genus, only two species are
52 holopelagic as they drift during their entire life cycle (Dawes and Mathieson, 2008) constituting
53 floating rafts called “the golden floating rainforest of the Atlantic Ocean” (Laffoley et al., 2011).

54 Morphological and molecular studies differentiated three genotypes: *S. fluitans* III and *S. natans*
55 I and VIII (Amaral-Zettler et al., 2017).

56 Historically holopelagic *Sargassum* spp. were present in the Caribbean Sea, at the edge of the
57 Gulf Mexico and the Azores islands (Lapointe, 1995). In summer 2011, unprecedented
58 quantities of *Sargassum* started to inundate the Caribbean Islands (Gower and King, 2011). In

59 some places such as northeastern Brazil, *Sargassum* stranded in locations have also spotted that
60 were never reported before (Széchy et al., 2012). In 2018, 20 million metric tons wet biomass
61 of Sargasso in the open Ocean formed a Great Atlantic Sargasso Belt extended for 8,850 km
62 length, since then, this Great Atlantic Sargasso belt is reported annually in the North Equatorial
63 Recirculation Region (NERR) (Wang et al., 2019).

64 The origins of the sudden and recurring increased of *Sargassum* abundance still remains unclear
65 (Ardhuin et al., 2019), and different hypotheses are proposed such as an increase in *i*) sea
66 surface temperature (Sissini et al., 2017), *ii*) nutrients released from Amazon and Congo rivers
67 (Oviatt et al., 2019) and *iii*) deposition of dust from African desert (Johns et al., 2020). The
68 stranding of *Sargassum* spp. on the coast areas have ecological issues threatening marina fauna
69 (Cipolloni et al., n.d.; Rodríguez-Martínez et al., 2019) including endangered species such as
70 sea turtles (Maurer et al., 2022, 2015; Ross and Casazza, 2008) and can lead to the
71 disappearance of coastal ecosystems (Gledhiir and Buck, 2012; van Tussenbroek et al., 2017).
72 Decomposition of abundant brown algae biomass accumulated in coastal environment liberates
73 toxic hydrogen sulphide (H_2S) (Reiffenstein et al., 1992) provoking important human health
74 issues such as respiratory diseases, neurological problems and cardiovascular lesions (Resiere
75 et al., 2018). *Sargassum* also represent an economic cost deterring tourism and obstructing free
76 circulation of boat impacting marine trade and fisheries (Langin, 2018).

77 Additionally, to these visible impacts, *Sargassum* can generate pernicious and invisible impacts
78 due to metal trace elements, contamination as it shows a high capacity of absorption of metals
79 and metalloids contaminants due to the high metallic affinity of alginate in their cell walls
80 (Davis et al., 1999; Vieira and Volesky, 2000; Volesky and Holan, 1995). Holopelagic
81 *Sargassum* spp. present high level of the total As with a concentrations fluctuating between
82 100 ppm and 145 ppm (Cipolloni et al., 2022; Dassié et al., 2021; Devault et al., 2020) and can
83 release this metalloid in coastal environments contaminating marine species (Cipolloni et al.,

84 n.d.). Arsenate absorbed by the algae is transformed in arsenite As(III) (Andreae and Klumpp,
85 1979; Howard et al., 1995). **Inorganic arsenic**, the most toxic form, represent a consistent and
86 substantial percentage of the total arsenic present in pelagic *Sargassum* spp. (Alleyne et al.,
87 2023). To our knowledge, the speciation of As released by *Sargassum* is not known.

88 However, this transfer is still poorly documented. Information on the kinetics and intensity of
89 those transfers in different coastal environments constitute an important information for the
90 implementation of coherent stranding management policy.

91 In addition of the metallic trace elements, the conditions of the experiments were also analyzed
92 in order to evaluate the physiological condition of the brown algae using their stable isotope
93 (Gager et al., 2021) composition and their phenolic compounds.

94 The aim of the present study was thus to experimentally determine the kinetics of accumulation
95 or depuration of 19 MTE during twenty-five days in three morphotypes of holopelagic
96 *Sargassum* arriving in three different coastal environments: *i)* coral reef *ii)* seagrass meadow
97 and *iii)* mangrove.

98

99 **2 Materials and methods**

100

101 **2.1 Study sites and experimental setting-up construction**

102 The Grand Cul-de-Sac marin (GCSM) in Guadeloupe (French West Indies) presents shallow
103 waters (less than 20m depth) bordered by a coral reef at the North and a mangrove at the South
104 (Guilcher and Marec, 1978). Over a period of 25 days during the month of July 2021, three
105 fixed experimental devices were placed in GCSM in the three different habitats (coral reef,
106 seagrass and mangrove) (Fig.1 A). Different habitats are localized at a distance at least 200m.
107 The coral reef is a natural bio constructed structure mainly composed of corals, followed by
108 seagrass forming dense underwater meadows and mangrove forest are closer to terrestrial
109 environment.

110 Each experimental device was composed of five floating plastic cages with dimension of 30 cm
111 in diameter and 20 cm in height. *Sargassum* freshly collected in the Petit Cul-de-Sac marin
112 (PCSM) were rapidly (less than one hour) placed in experimental device. Control sample (n=3)
113 at the beginning of incubation (t=0) were collected, of each species. A fixed fresh weight of
114 approximately 60g of *Sargassum* of the mixed three morphotypes (*S. fluitans* III and *S. natans*
115 I and *S. natans* VIII) was separated morphologically at the experimental devices stations and
116 placed in each cage (Fig.1) BAAt different temporal intervals (days 1, 4, 11, 18 and 25)
117 macroalgae contained in each cage were simultaneously sampled in each habitat (coral reef,
118 seagrass meadow, mangrove). After collection, each sample was separated by genotypes,
119 placed in paper wraps and oven-dried during 48 h at 50°C. In total, 47 samples were collected
120 during the experiment and one sample was missing due to disappearance of *S. natans* VIII in
121 the last sampling cage in mangrove.

122

123 **2.2 Laboratory analyses**

124

125 ***Biomass analysis and laboratory preparation***

126 After the drying step, each *Sargassum* morphotype sample was weighed. The samples were
127 then ground and homogenized using a vibro-grinder with zirconium balls of 10 mm for three
128 min with a frequency of 30 beat/s (Retsch® MM 400). Grounded samples were used to carry
129 all the following measurements: stable isotope, phenolic compounds and MTE levels.

130

131 ***Phenolic compounds analysis***

132 Phenolic compounds were extracted twice using 15 mg DW of algal powder in 1 mL of 70 %
133 ethanol according to a modified method from (Zubia et al., 2009). The extractions were carried
134 out with an ultrasonic bath (Sonicator 88155, Fisher 160 Bioblock Scientific, France) during

135 15 min at 4 °C followed by 2 h at 40 °C under magnetic stirring. Then, samples were centrifuged
136 for 10 min at 8,000 rpm (Eppendorf Centrifuge 162 5810, Germany) and supernatants were
137 pooled and evaporated at 40 °C using a centrifugal concentrator (miVac, Genevac, France).
138 Total phenolic content (TPC) was determined using the Folin-Ciocalteu colorimetric assay
139 modified from (Zubia et al., 2009). Thus, 20 µL of sample was added to 130 µL of distilled
140 water, 10 µL of Folin-Ciocalteu reagent and 40 µL of sodium carbonate (Na₂CO₃, 200 g.L⁻¹).
141 Then microplates were incubated for 10 min at 70 °C before absorbance reading in triplicate at
142 620 nm (Multiskan FC, Thermo Scientific, USA). TPC was determined using a standard curve
143 of phloroglucinol (1,3,5-trihydroxybenzene) and expressed in milligrams per gram of the dried
144 seaweed powder (mg.g⁻¹ DW) and in percentage of TPC against day 0 level to see the evolution
145 of *Sargassum* phenolic content during the experiment.

146

147 ***Isotope analysis and calculation***

148 The δ¹⁵N and the δ¹³C isotopic compositions of each *Sargassum* samples (*S. fluitans* III and
149 *S. natans* I and *S. natans* VIII) from the experimental devices were measured by EA-IRMS
150 (Elemental Analysis – Isotope Ratio Mass Spectrometry) (Narancic et al., 2017). The isotopes
151 compositions were expressed as δ – values relative to reference standard in per mil (‰) such
152 as nitrogen composition is expressed in delta notation as:

$$153 \quad (\delta^{15}N) = \left[\frac{\left(\frac{^{15}N}{^{14}N} \right)_{sample}}{\left(\frac{^{15}N}{^{14}N} \right)_{reference}} - 1 \right] \times 100$$

154

155

156 ***Metal(loid)s trace elements analysis***

157 A series of 19 elements (Ag, Al, As, Ba, Cd, Co, Ca, Cr, Cu, Fe, Gd, Mn, Mo, Ni, Pb, Se, Sr,
158 V, and Zn) were analyzed using an Inductively Coupled Plasma Optical Emission Spectrometer
159 (Spectrometer ICP-OES 700®, Agilent Technologies). Certified reference materials DOLT-5

160 (dogfish (*Squalus acanthias*) liver), TORT-3 (Lobster Hepatopancreas), and IAEA-413
161 (Algae) were analyzed using ICP-OES, their recovery rates vary between $84,1 \pm 3,33$ and
162 $111,6 \pm 0,21$ (Table 1). For the values below the instrument detection limit, theoretical minimum
163 concentration values are calculated (the detection limit of the instrument (in $\mu\text{g. g}^{-1}$) multiplied by
164 the volume of the sample (in L) divided by the sample *Sargassum* weight (in g)).
165 For each sample, a fixed amount of algal powder (70-80mg) was placed in a plastic tube and
166 acidified by the addition of 1 mL of nitric acid (HNO_3 67%). The powdered sample was then
167 mineralized for 3 h at 100°C (Environmental – EXPRESS HotBlock® - 54). After
168 mineralization, 5 mL of deionized water was added to each sample. With identical process,
169 certified reference materials (DOLT-5, TORT-3, IAEA-413) were analyzed and were
170 systematically in the concentration range. The metal concentrations in *Sargassum* samples were
171 expressed in $\mu\text{g.g}^{-1}$ (ppm) dry weight.

172

173 **2.3 Data analysis**

174 The variance and the homogeneity of metals and metalloid concentration values were verified
175 by the Shapiro's and Levene's tests, respectively (with significance at the 95% confidence
176 level). As normality was not observed, the differences between means concentrations in
177 genotypes per habitat and in all habitats were tested using the non-parametric test Kruskal-
178 Wallis test. Principal Component Analyses (PCA) were executed on RStudio® and RCran,
179 using the following packages: FactoMiner (Husson et al., 2020), factoextra (Kassambara and
180 Mundt, 2020), ggplot (Wickham et al., 2020) and corrplot (Wei et al., 2021) to select the MTE
181 with higher influence in data structuration between the 19 elements (Al, As, Cd, Co, Cr, Cu,
182 Fe, Mn, Ni, Pb, Se, Sr, V, and Zn). Metallic elements (Co, Pb, Se, and Sr) below the limit of
183 detection (LOD), were not considered.

184

185 **3 Results**

186

187 **3.1 Indicators of the physiological condition of *Sargassum*: biomass, phenolics**
188 **contents and isotopic signatures.**

189

190 There were two distinct phases in the physiological state of the algae. The biomass of each
191 morphotype of *Sargassum* (*S. fluitans* III, *S. natans* I and VIII) in the three habitats (coral reef,
192 seagrass meadow and mangrove) regularly increased after the beginning of the experiment and
193 started to decrease after the day 18 (Fig.2).

194 In the three habitats, phenolic contents of each morphotype also follows similar kinetics with
195 two distinct phases, *i*) a first phase of decrease in phenolic content compounds until the 11th
196 days, and *ii*) a second phase with an increase in phenolic content from the 18th day to the end
197 of the experiment (Fig.2). The phenolic content in $\mu\text{g. g}^{-1}$ was higher in the morphotype
198 *S.fluitans* III, (25 and 30 $\mu\text{g. g}^{-1}$) than in *S.natans* I (10 and 20 $\mu\text{g. g}^{-1}$) and *S.natans* VIII
199 (10 and 12 $\mu\text{g. g}^{-1}$).

200 Isotopic compositions ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) of *Sargassum* were not clearly differ
201 rent between all habitats and morphotypes. The values of the isotopic signature in the three
202 habitats, for the three genotypes remains around (3%-4%) for the $\delta^{15}\text{N}$ and 14%-18% for the
203 $\delta^{13}\text{C}$.

204

205 **3.2 Metals and metalloids content**

206

207

208 Ten elements (Al, As, Cd, Cu, Fe, Mn, V, Ni, Cr and Zn) were the most abundant and were
209 detected in all samples above the limit of detection (LOD). The elements Ag, Co, Sr, Se, Mo,
210 Gd, Ca, Pb and Ba were below the LOD. (Table 1)

211 The variability of the data analyzed, has been verified by tri-replicates on the measurements of
212 the samples analyzed.

213 Kinetics analysis were focused on the five metallic elements standing out in PCA analysis (Al,
214 As, Fe, Cu and Zn). Three kinetics profiles are observed: *i*) a significant decrease contamination
215 (As), *ii*) an increase in contamination (Zn) and (Cu) *iii*) a bell-shaped profile (Al and Fe) (Fig.3).

216

217 **3.3 Principal Component Analysis (PCA)**

218

219

220 Principal Component Analysis (PCA) was used to evaluate the influence of habitat and
221 *Sargassum* morphotype on metallic elemental concentrations. The first two dimensions of PCA
222 representing respectively 38.83% (F1) and 13.17% (F2) of the total variance (Fig 4.A). F1
223 distinctly discriminates the variables Al (13.37%), Fe (14.45%), Zn (14.08%), and Cu
224 (15.25%), whereas and F2 clearly discriminates As (11.65%).

225 The PCA analysis of the sample discriminates the mangrove habitat characterized by high
226 concentrations in Fe, Al, Zn, Cu and As in *Sargassum* (Fig.4 B) whereas samples from seagrass
227 meadow and coral reef were similar with high concentrations of Ni, V, Cd and Cr. PCA
228 discrimination according to *Sargassum* by the day (Control; Day=1; Day=4, Day=11, Day=18
229 and Day=25) showed that the evolution of the variability of MTE concentrations increased
230 between inter-habitats. Except, for the Day 25th with lower concentration in metallic elements
231 (Fig.4 B). On the PCA analysis whatever the habitat, and the experiment duration, each of the
232 three morphotypes followed similar trend (Fig. 4 B).

233

234

235 **4 Discussion**

236

237 The present study measured the kinetics of metal(oid)s trace elements contaminations of
238 holopelagic *Sargassum* (*S.fluitans* III and *S.natans* I and *S.natans* VIII) remaining floating in
239 three different tropical coastal environments. Different kinetics patterns were observed
240 according to *i*) MTE *ii*) coastal environments with highest fluctuations in mangrove *iii*) and
241 morphotype due to the singularity of the genotype *S. natans* I.

242 In our sample entire macroalgal thalli were dried and ground before the analyzes and each
243 morphological character (leaves, stems, bladders) was not separately analyzed masking
244 potential specificities of metal concentrations in each algal tissue (Sadeghi et al., 2014).
245 However, in our samples were homogeneous, and triplicates of the measures were realized,
246 which removes the bias of the measures.

247 Environmental parameters were not measured during the experiments as each habitat presented
248 many specificities making the identification of most structuring variable complex. As a result,
249 the present experimental approach in *situ* did not allow to identify the specific role played by
250 each variable but provided results realistically transposable to *in situ* field conditions. Those
251 field conditions are representative of each habitat with a classical decreased gradient of
252 terrestrial influence from mangrove to coral reef. Mangrove are consequently classically more
253 influenced by freshwater and organic matter inputs than the two other habitats.

254 A similar evolution of algal biomasses was generally observed in all samples whatever the
255 morphotype and habitat with a first increase in biomass followed by a decrease. This decrease
256 is likely due to the degradation of seaweeds indicating unsuitable conditions. Physiological or
257 stress conditions of algae were also evaluated measuring phenolics contents (Plouguerné et al.,
258 2006). Phenolic compounds of brown seaweeds or phlorotannins are present sometimes in high
259 level, between (10 % and 120%) in the cells walls and the physodes and as there are produced
260 in response to any changes in abiotic (temperature, light) and biotic (grazing, fouling) factor,
261 their content may be used to evaluate algal stress (Arnold and Targett, 2002; Ragan and Craigie,

262 1976; Schoenwaelder and Clayton, 1999). Seaweed samples were oven-dried at 50°C and this
263 process can alter phenolics compounds (Gager et al., 2021), however a similar drying method
264 was applied for all samples allowing inter-samples comparisons in the evolution of the phenolic
265 content compared to the beginning of the experiment. The evolution of phenolics contents was
266 generally observed in all samples whatever the morphotype and habitat with a first decrease of
267 phenolic compounds between the day 0 (Day=D0) to the day four (Day=D4). During this initial
268 phase, the stress of algae would be limited and their biomass would increase. During the second
269 phase, the content of phenolic compounds in algae increased, between the day four (Day=D4)
270 and the day twenty-five (Day=D25) potentially due to their production by algae and/or the
271 degradation of the algal thallus with increasing proportion of phenolic compounds from less
272 degraded cell walls were still within the thalli and in proportion, their content expressed in
273 $\mu\text{g}\cdot\text{g}^{-1}$ algal dw increased (Koivikko et al., 2005; Schoenwaelder and Clayton, 1999). The
274 temporal variation in phenolic contents therefore suggest that the algae are first in good
275 condition, then stressed, leading to the degradation of the algae and its death. Evolution of
276 isotopic composition ($\delta^{15}\text{N}$ and $\delta^{13}\text{C}$) of algae during the experiments can reflect the uptake
277 of C and N from the environment and/or the preferential disappearance of isotope form during
278 the degradation process. However, no clear trend was observed during the experiment
279 suggesting that stable isotope would not be adapted to evaluate physiological state of
280 *Sargassum* in this type of experiment. The evolution of biomass and phenolic compounds, with
281 the used of trireplicates, both suggest that environmental conditions in cages are stressful for
282 *Sargassum* and conduct to the death of algae during the experiments. A similar laboratory
283 experience with *Sargassum* in mesocosm bags during 26h showed a rapid degradation of the
284 macroalgae (Devault et al., 2021) which is in agreement with our study.

285 Initial metals and metalloids concentrations of *Sargassum* used in the present experiment were
286 similar to values previously measured in seaweeds collected in coastal areas (García-Sartal,

287 2012; Rodríguez-Martínez et al., 2020). However *S.natans* I presented metal(oid)s
288 concentrations standing out from values of the two others morphotypes whereas this outsider
289 role was played by *S.natans* VIII in previous studies (Cipolloni et al., 2022; Dassié et al., 2021).
290 Kinetics of *Sargassum* metal(loid) concentrations followed three different kinetics: *i*) a
291 significant decrease in contamination (As), *ii*) a significant increase in contamination (Zn and
292 Cu) *iii*) a bell-shaped profile (Al and Fe).

293 Marine organisms incidentally take up As through different transporters like the phosphate
294 transporter (Garbinski et al., 2019; Saberzadeh Sarvestani et al., 2016). Arsenic can derive in
295 arsenate pentavalent AsO_4^{3-} and this form is similar to the phosphate ion and can consequently
296 enter in algae using phosphate transporter pathway (Gobert et al., 2022). In order to tolerate
297 such cellular absorption, algae limit As entrance in cytosol (Garbinski et al., 2019) and
298 accumulate the majority of As as hydrophilic compounds in the cells (Ender et al., 2019). This
299 specific distribution of As could be an explanation of the rapid release of As counterbalanced
300 by an increase of other metallic elements like the Fe, Cu, Zn and Al (Delshab et al., 2016;
301 Gobert et al., 2022). This mechanism would explain antagonism between As and Fe
302 concentrations in *Sargassum* previously observed in experimental (Mamun et al., 2019) and *in*
303 *situ* conditions (Cipolloni et al., 2022).

304 Due to the proximity with land, coastal environments are more enriched in organic matter than
305 offshore ones. Degradation of this organic matter in coastal area sediment induce hypoxic
306 conditions resulting in high contents of metallic elements like Fe, Cu, Zn and Mn (Holloway et
307 al., 2016; Rezaei et al., 2021). The increase in metal elements in *Sargassum* can be explained
308 by the carboxylate group within alginates (cell wall polysaccharides) of the algae presenting an
309 extremely high affinity with divalent metals like Cu, and Zn (He and Chen, 2014). This
310 increased fixation of metallic elements by *Sargassum* would induce the release of As as
311 previously suggested in the present study.

312 In all the study in the three different coastal environments, metallic elements present high
313 temporal fluctuations with higher fluctuations in mangrove habitat.

314 Due to higher proximity with terrestrial environment and high primary production, the
315 mangrove is characterized by higher amount of OM, than the two other habitats. The OM can
316 potentially influence the metal availability. Suspended OM present high affinity with metal
317 elements and form different complexes (Doig and Liber, 2006). Chelation and sequestration of
318 pollutants in mangrove (Bastakoti et al., 2019) would consequently reduce their bioavailability
319 implying a release of this compounds by *Sargassum*. In accordance with this hypothesis
320 *Sargassum* were previously observed depurating As due to competitive exchange with
321 terrigenous metals (Gobert et al., 2022). Salinity variations are more important in the mangrove
322 than in other habitat due to mainland proximity and decreased salinity specific physiological
323 and morphological processes of mangrove organisms (Clough et al., 1989; Feller et al., 2010).

324 As OM, salinity could leads to the formation of stable metal-chloride complexes decreasing the
325 availability of metallic elements (Mader et al., 1995). In mangrove, the decreased salinity and
326 increased content of organic matter have opposite effects on metallic elements complexation.

327 The observed releasing activity of metalloids (As) by *Sargassum* in mangrove suggests that
328 OM is more structuring than salinity and reduce metals availability in this environment.

329 One morphotype, *S.natans* I stand out of PCA analyzes in the mangrove. In this environment
330 kinetics of As and Zn contents were faster in *S. natans* I than for the two other morphotypes (*S.*
331 *natans* VIII and *S. fluitans* III). This specificity of metallic concentration of the morphotype *S.*
332 *natans* I was previously observed (Davis et al., 2021; Gobert et al., 2022). This difference could
333 be due to its morphology particularity as *S. natans* I presenting a more complex structure with
334 higher exchange surface favoring fixation or release of pollutants (Khotimchenko et al., 2001).

335 Compared to other morphotypes *S. natans* I also present a specific chemical composition,
336 *S.natans* I appears to be significantly more enriched in P compared to the others morphotypes

337 (Gobert et al., 2022). The ability of *S.natans* I to absorb pollutants may notably be due to its
338 alginates which may have a different structure compared to the two other *Sargassum* genotypes
339 as length alginates limit the retention of some cations such as metals (Rhein-Knudsen et al.,
340 2017).

341 The stranding of *Sargassum* causes visible impacts on environment, economy and public health
342 (Resiere et al., 2018; van Tussenbroek et al., 2017). Several solutions have consequently been
343 considered to limit the impacts of *Sargassum* in coastal environments (Robledo et al., 2021).
344 Less visible impacts such as As contamination of algae must be considered in those strategic
345 choices of *Sargassum* management.

346 The total Arsenic is the most widely distributed element in the marine environment with a
347 complex biogeochemistry (Fattorini et al., 2006; Neff, 1997). Arsenic concentrations obtained
348 in the present study are in the range of the values previously observed in *Sargassum* collected
349 in coastal, with values between 80 and 150 ppm (Cipolloni et al., 2022; García-Sartal, 2012;
350 Rodríguez-Martínez et al., 2020) and off-shore environments with values a mean of 140 ppm
351 (Cipolloni et al., 2022; Dassié et al., 2021). Those values are above European norms for
352 products intended for human consumption (European Commission, 2019). Our study revealed
353 that, once arrived in coastal environment, *Sargassum* rapidly release their As and this
354 characteristic is observed for all morphotype and coastal ecosystem studied.

355 Marine algae accumulating As usually biotransform it once in the cells (Alleyne et al., 2023).
356 Brown algae plant have set up a regulation mechanism in order to reduce the toxicity of As
357 (Howard et al., 1995; Sanders and Windom, 1980). The major part of the arsenate absorbed by
358 the algae is transformed in arsenite As(III) (Andreae and Klumpp, 1979; Howard et al.,
359 1995)(Andreae and Klumpp, 1979; Howard et al., 1995; Sanders and Windom, 1980) and then
360 stocked in the brown algae in the form of nontoxic arsenosugars (Francesconi and Edmonds,
361 1996). Experiments conducted with caged *Sargassum* suggest a rapid release of As (Chapitre

362 III). However, the speciation of As released by *Sargassum* is not known and this form could be
363 non-bioavailable explaining the absence of increased As in organisms adjacent to *Sargassum*
364 accumulations.

365

366 Conclusion and perspectives.

367

368 To avoid this transfer of As from *Sargassum* spp. to coastal environment, dams can be used to
369 deviate macroalgae or stop them before stranding. Dams must be placed as far away from coast
370 as possible and trapped algae must be collected rapidly. In our study, **the As is the metalloid**
371 **the more fastest released element with a decreasing contamination. Among the element above**
372 **LOD, Al and Fe have a bell-shaped kinetics contamination whereas element (Zn) present an**
373 **increasing contamination. Phenolics compounds and reveals the algal stress during the**
374 **experiment”**

375 Limited release of As by *Sargassum* implies that collected algae will presents a high As
376 concentration that must be considerate for their further valorization. The use of *Sargassum* as
377 fertilizers (Milledge and Harvey, 2016) represent a potential risk of contamination of
378 agricultural lands. Public health could potentially be impacted when *Sargassum* are used as
379 food for cattle or as drugs (Velasco-González et al., 2013) and as textiles and papers (Oyesiku
380 and Egunyomi, 2014). High content of As would present a limited risk when *Sargassum* spp.
381 are used to produce biogas (López Miranda et al., 2021) constituting the less risk valorization
382 solutions.

383 The release of As by stranded *Sargassum* has already been shown to increase As contamination
384 of coastal organisms representing a risk for seafood consumers (Cipolloni et al., n.d.). The
385 present study reveals that this transfer from *Sargassum* is rapid in all coastal zone and must be
386 considered when managing *Sargassum* inundation event.

387

388

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394

395

396 **Ethical Approval**

397 This manuscript is an original work and has not been previously published somewhere else not
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399

400

401 **Consent to participate**

402 Not applicable

403

404 **Consent for publication**

405 The authors consented

406

407 **Author contribution**

408

409 All authors contributed to the study conception and design. The first draft of the manuscript
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426

427 **Competing interest**

428 The authors declare no competing interest

429

430 **Availability of data and materials**

431 All the revelant data are within the paper

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436 **Bibliography**

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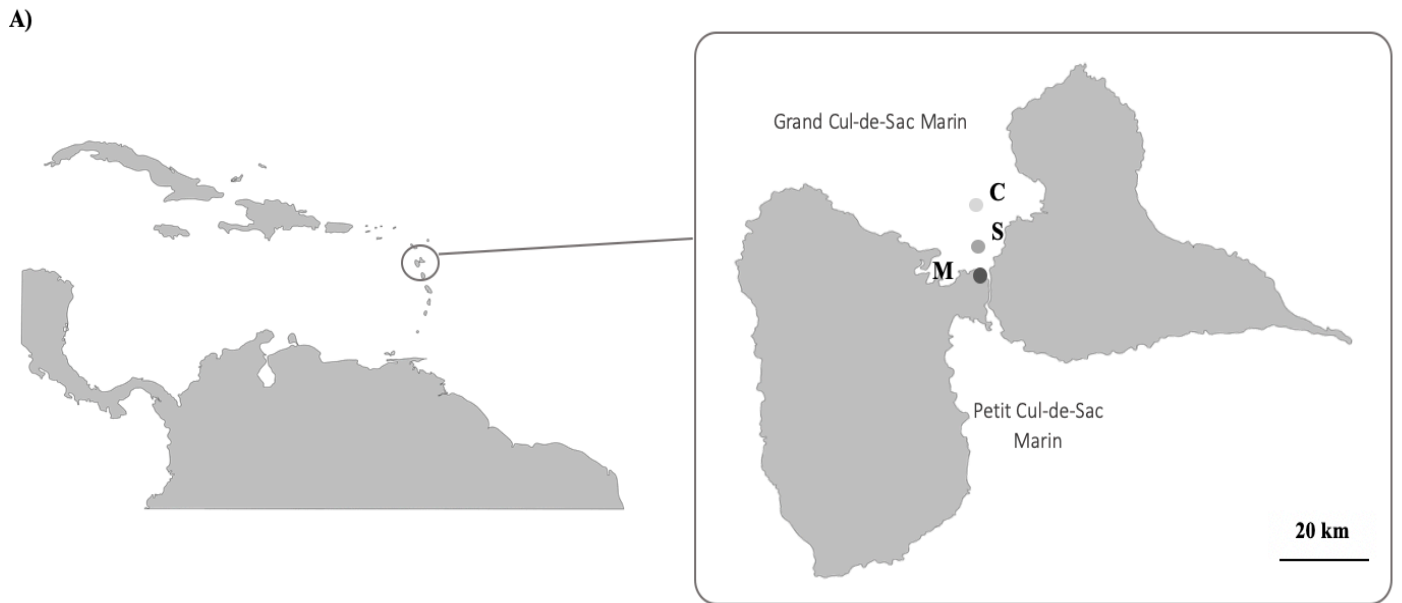
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B)

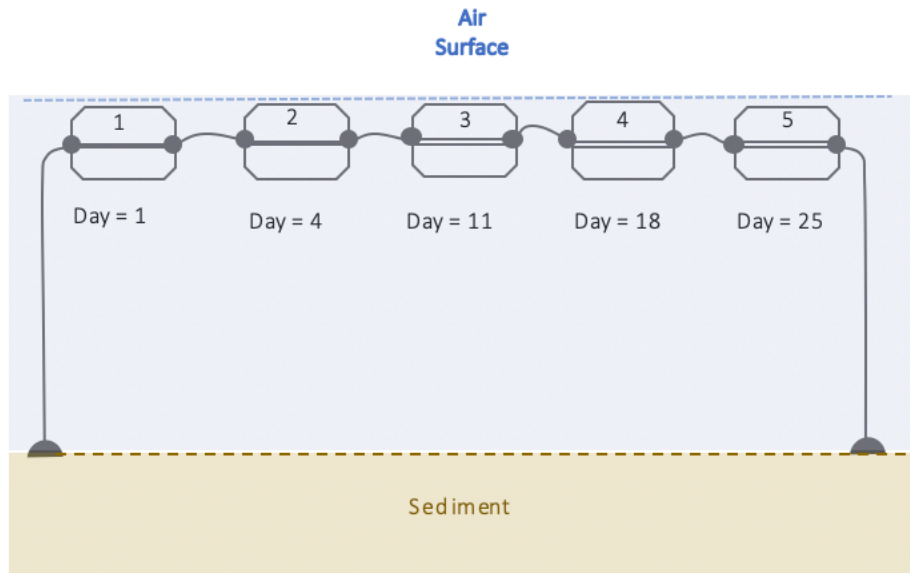
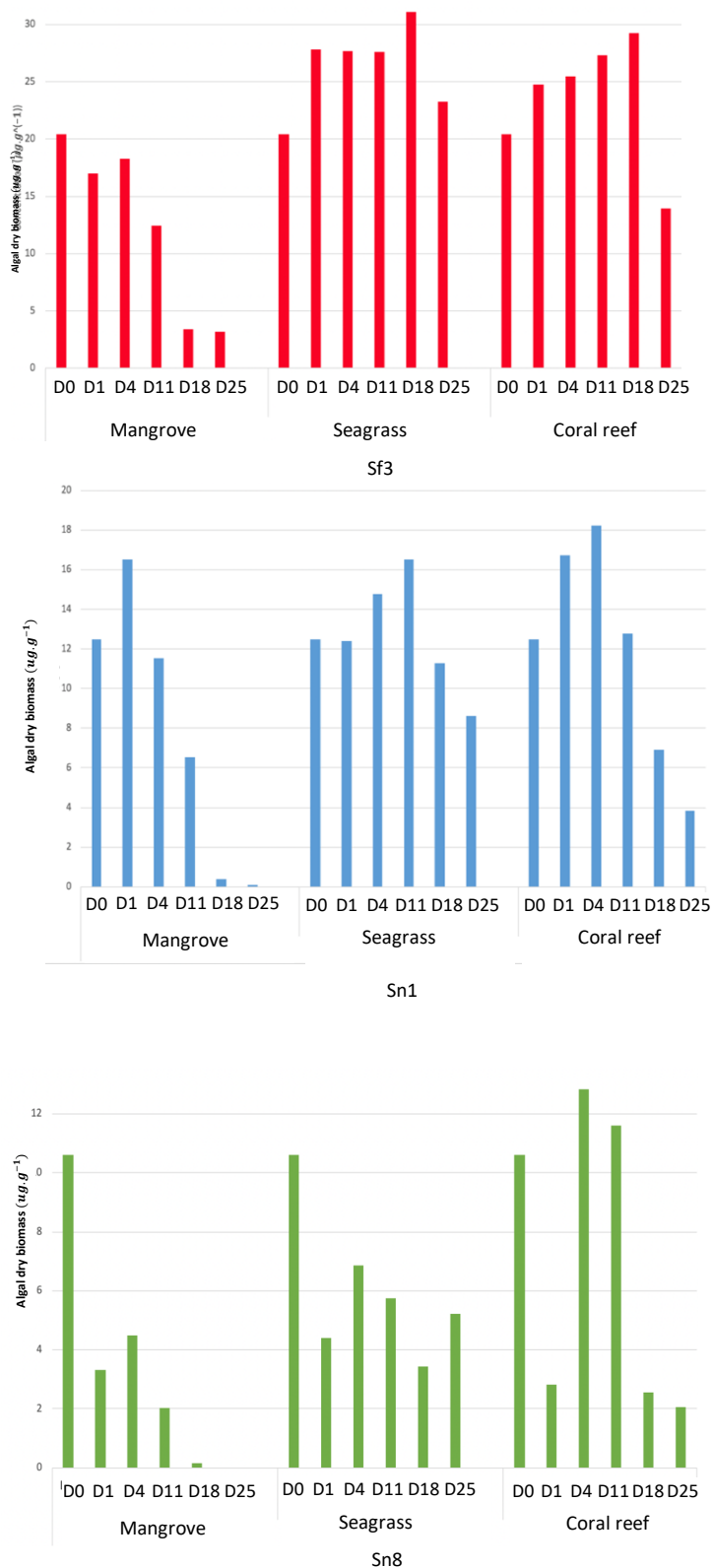


Figure 1 Sampling site and experiments setting up. **Figure 1.A** Location of the sampling sites experimentation: CR (coral reef) ($8^{\circ}02'N$; $-47^{\circ}07'W$), H (seagrass meadow) ($6^{\circ}87'N$; $-34^{\circ}42'W$), M (mangrove) ($6^{\circ}98'N$; $-31^{\circ}80'W$) of the prototype experimentation during July 2020. **Figure 1.B** Floating cages containing *Sargassum* recovered at Day=1, 4, 11, 18 and 25).

		<i>Al</i>	<i>As</i>	<i>Fe</i>	<i>Cu</i>	<i>Zn</i>
<i>Control Mangrove</i>	Day=0	123±2,0	74,0±0,1	101±3,1	2,2±0,06	5,1±0,06
	Day=1	251,6±24,2	74,9±0,3	581,5 ± 17,6	2,5±0,1	21,03±0,06
	Day=4	1279±77,9	67,8±0,7	1424,5±86,5	4,6±0,1	32,2±0,4
	Day=11	1089,5±20	53±0,7	1068,9±15,9	4,5±0,05	47,8±0,5
	Day=18	1180±22,5	50,9±0,0	869,5±13,5	4,5±0,06	60,9±0,7
	Day=25	NA	48±0,08	1518,7±76,1	6,03±0,1	98,1±0,2
Mean		784,6	61,47	1112,8	4,9	53,09
<i>Seagrass</i>	Day=1	440,6±19,4	70,5±1,07	680,4±9,01	3,2±0,12	21,7±0,2
	Day=4	501,1±25,5	64,6±1,1	438,1±28,1	2,6±0,02	12,9±0,3
	Day=11	781,05 ± 8,9	50,7±0,02	612,9±4,2	2,9±0,02	26,6±0,09
	Day=18	890,2±10,00	39,02±0,2	549,7±3,9	2,7±0,08	30,3±0,5
	Day=25	NA	36,4±0,09	711,80±5,8	2,6±0,03	34,8±0,40
	Mean		653,2	52,2	598,8	2,84
<i>Coral reef</i>	Day=1	384,8±20,5	74,5±0,2	309,6 ± 15,6	2,1±0,03	9,3±0,1
	Day=4	640,3±16,07	64,7±0,5	492,3±9,5	2,8±0,02	2,5±0,02
	Day=11	763,7 ± 14,6	44,9±0,5	486,1±12,8	2,9±0,06	23,2±0,3
	Day=18	1072,4±28,1	40,00±0,1	656,5±18,7	2,9±0,08	35,5±0,2
	Day=25	NA	37,08±0,3	998,9±4,3	2,8±0,13	31,4±2,2
	Mean		715,3	52,2	588,7	2,7
<i>IAEA413 recovery rate (%SD)</i>			101,29 ± 4,66	96,76±44,39		97,66±7,33
<i>DOLT-5 recovery rate (%SD)</i>			99,93±0,58	91,21±24,59	100,12±0,61	99,91±2,36
<i>TORT-3 recovery rate (%SD)</i>			111,67±0,21	84,15±3,33		96,36±0,91

Table 1. Elements concentration (ppm = $\mu\text{g. g}^{-1}$) of pelagic *Sargassum* spp. collected from the three habitats (coral reef, seagrass, mangrove) Ocean to the Lesser Antilles (Guadeloupe – French West Indies) with their respective standard error (standard deviation divided by the squared root of the number of data), and the average in bold. Below the table there are recovery rates obtained from the analyses of certified reference material (TORT-3, DOLT-5, IAEA 413, and IAEA 407).

A)



B)

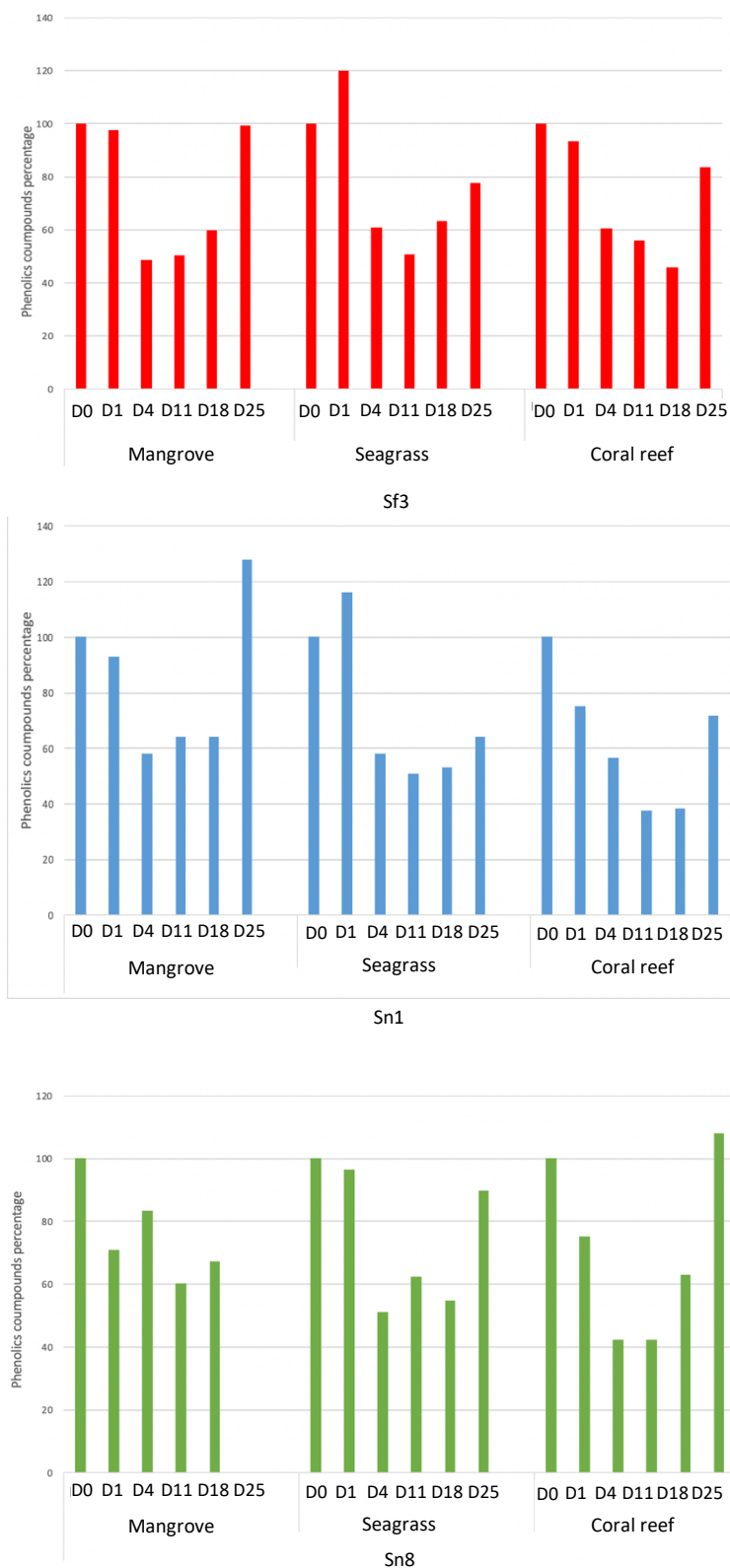


Fig 2. Algal dry biomass in $\mu\text{g.g}^{-1}$ (Fig 2.A) and phenolics content (%) (Fig 2.B) of *Sargassum* algae collected from the three different habitats (coral reef, seagrass and mangrove) for the three morphotypes of *Sargassum* sp. (*S. fluitans* III (SF3); *S. natans* I (SN1) and *S. natans* VIII (SN8)) during twenty-five days (0, 1, 4, 11, 18 and 25).

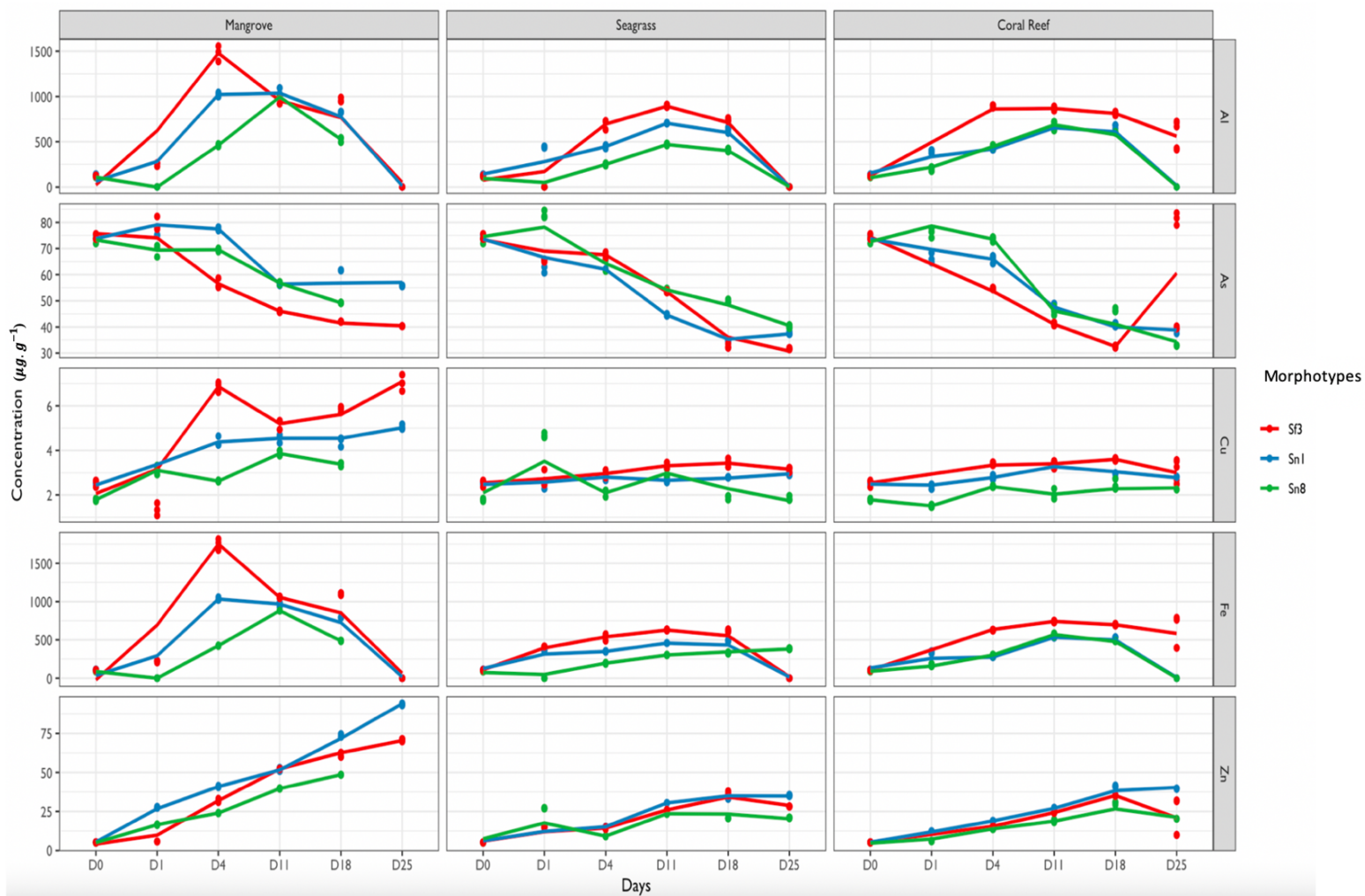


Fig 3. Temporal variability of metal concentrations. Concentrations in Al, As, Cu, Fe and Zn ($\mu\text{g.g}^{-1}$) in *Sargassum* algae collected from the three different habitats (coral reef, seagrass and mangrove) for the three morphotypes of *Sargassum* spp. (*S. fluitans* III (Sf3); *S. natans* I (Sn1) and *S. natans* VIII (Sn8)) during twenty-five days (Days 0, 1, 4, 11, 18 and 25).

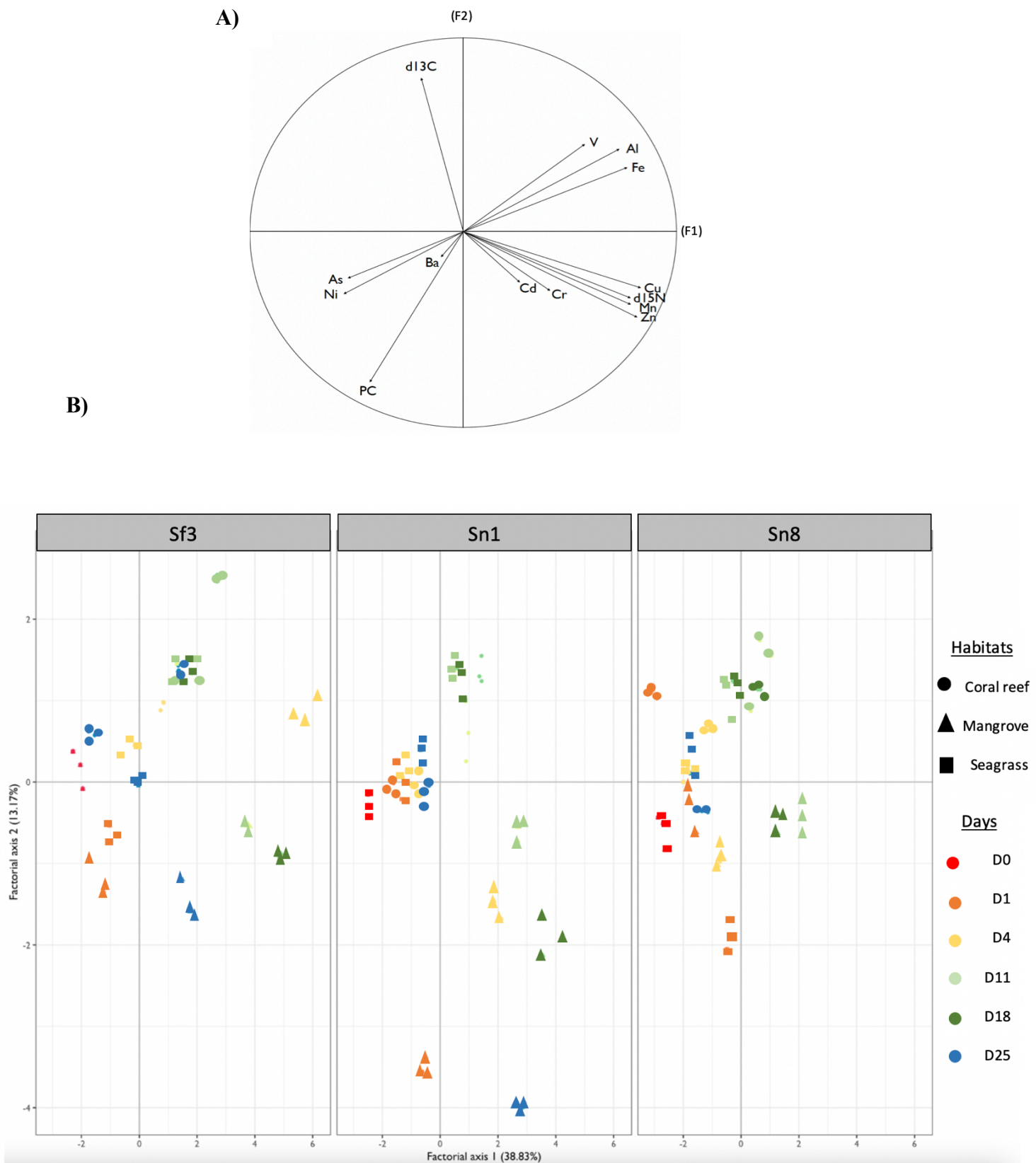
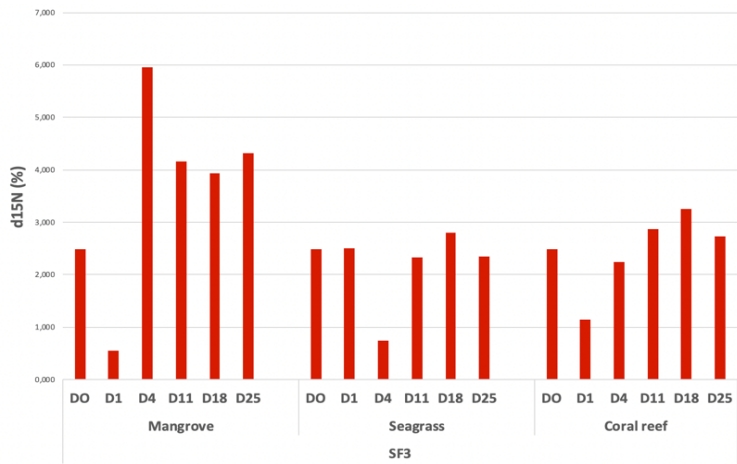


Fig 4. Principal Component Analyses (PCA) showing variables (Fig.4 A) and Temporal Principal Component Analyses (Fig.4 B). F1 (38.82%) and F2 (13.17%) represents the relationship in *Sargassum* sp. between all the metallic elements (As; Ni; Ba; Cd; Cr; Zn; Cu; Mn, Fe; Al and V), the isotopic signature ($\delta^{15}N$ and $\delta^{13}C$) and the phenolic content (PC) (Fig.4 A). Symbols shapes represent different coastal environments (coral reef, seagrass and mangrove) and colors represent different days (0,1, 4,11, 18 and 25).

A)



B)

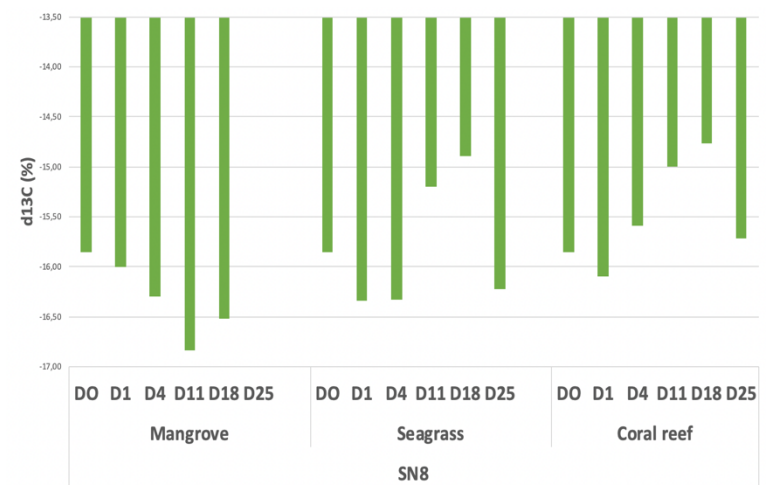
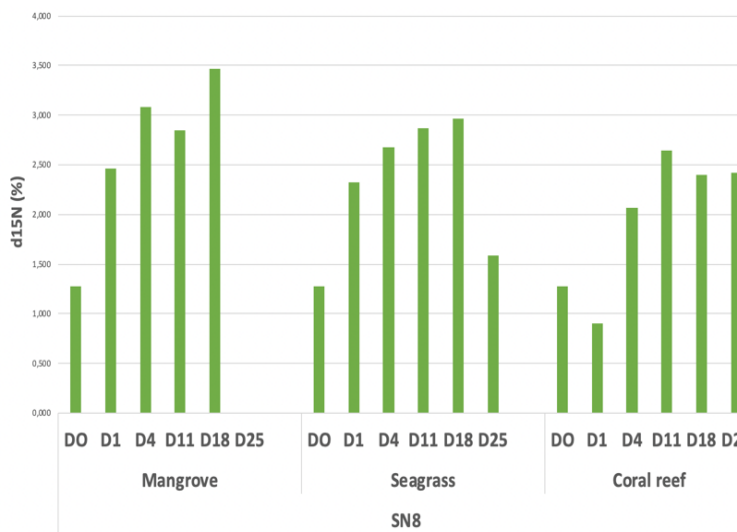
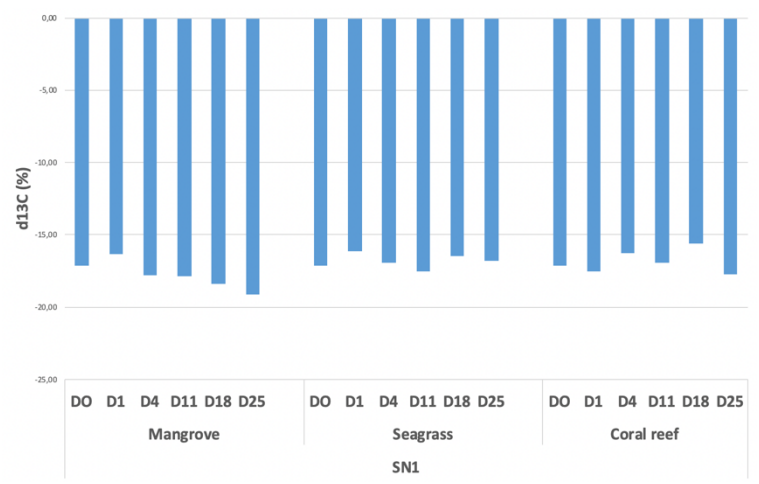
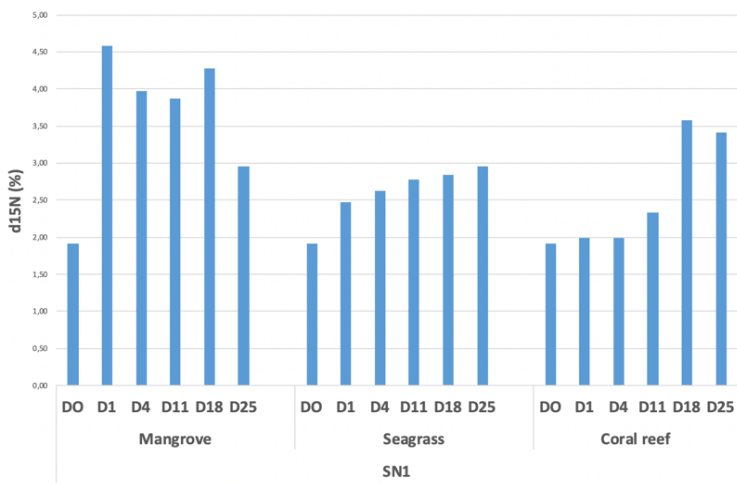
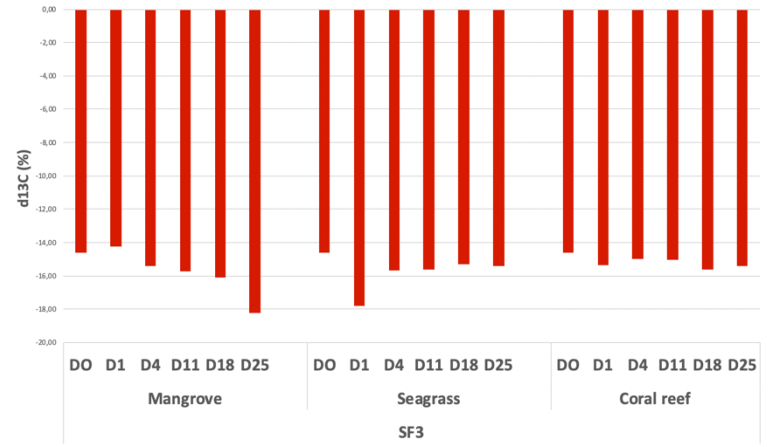


Fig (supplement). Isotopic signature for $\delta^{15}N$ (A) and for $\delta^{13}C$ (B) of *Sargassum* algae collected from the three different habitats (coral reef, seagrass, mangrove) for the three morphotypes of *Sargassum* spp. (*S. fluitans* III (SF3); *S. natans* I (SN1) and *S. natans* VIII (SN8)) during twenty-five days (0, 1, 4, 11, 18 and 25).

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Table 1. Elements concentration (ppm = $\mu\text{g. g}^{-1}$) of pelagic *Sargassum* spp. collected from the three habitats (coral reef, seagrass, mangrove) Ocean to the Lesser Antilles (Guadeloupe – French West Indies) with their respective standard error (standard deviation divided by the squared root of the number of data), and the average in bold. Below the table there are recovery rates obtained from the analyses of certified reference material (TORT-3, DOLT-5, IAEA 413, and IAEA 407).