

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

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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.

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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 $\mu\text{g} \cdot \text{g}^{-1}$) 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 $\mu\text{g} \cdot \text{g}^{-1}$ (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,

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

Initial metals and metalloids concentrations of *Sargassum* used in the present experiment were 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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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**

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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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427 **Competing interest**

428 The authors declare no competing interest

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431 All the relevant data are within the paper

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436 **Bibliography**

437

438 Alleyne, K.S.T., Neat, F., Oxenford, H.A., 2023. An analysis of arsenic concentrations
439 associated with sargassum influx events in Barbados. *Mar. Pollut. Bull.* 192, 115064.

440 <https://doi.org/10.1016/j.marpolbul.2023.115064>

441 Amaral-Zettler, L.A., Dragone, N.B., Schell, J., Slikas, B., Murphy, L.G., Morrall, C.E.,

442 Zettler, E.R., 2017. Comparative mitochondrial and chloroplast genomics of a
443 genetically distinct form of *Sargassum* contributing to recent “Golden Tides” in the
444 Western Atlantic. *Ecol. Evol.* 7, 516–525. <https://doi.org/10.1002/ece3.2630>

445 Andreae, M.O., Klumpp, D., 1979. Biosynthesis and Release of Organoarsenic Compounds
446 by Marine Algae. *Environ. Sci. Technol.* 13, 738–741.
447 <https://doi.org/10.1021/es60154a001>

448 Arduin, F., Brandt, P., Gaultier, L., Donlon, C., Battaglia, A., Boy, F., Casal, T., Chapron,
449 B., Collard, F., Cravatte, S.E., Delouis, J.M., de Witte, E., Dibarboure, G., Engen, G.,
450 Johnsen, H., Lique, C., Lopez-Dekker, P., Maes, C., Martin, A., Marie, L., Menemenlis,
451 D., Nouguié, F., Peureux, C., Ressler, G., Rio, M.H., Rommen, B., Shutler, J., Suess,
452 M., Tsamados, M., Ubelmann, C., Sebille, E. Van, van der Vorst, M., Stammer, D.,
453 Rampal, P., 2019. SKIM, a candidate satellite mission exploring global ocean currents
454 and waves. *Front. Mar. Sci.* 6. <https://doi.org/10.3389/fmars.2019.00209>

455 Arnold, T.M., Targett, N.M., 2002. Marine tannins: The importance of a mechanistic
456 framework for predicting ecological roles. *J. Chem. Ecol.* 28, 1919–1934.
457 <https://doi.org/10.1023/A:1020737609151>

458 Bastakoti, U., Robertson, J., Bourgeois, C., Marchand, C., Alfaro, A.C., 2019. Temporal
459 variations of trace metals and a metalloid in temperate estuarine mangrove sediments.
460 *Environ. Monit. Assess.* 191. <https://doi.org/10.1007/s10661-019-7916-z>

461 Cipolloni, O.-A., Couture, P., Pascal, P.-Y., n.d. (in prep-a) Temporal fluctuation of metallic
462 and metalloid concentration in three morphotypes of floating holopelagic *Sargassum*
463 from the Caribbean coast (Guadeloupe, French West Indies).

464 Cipolloni, O.A., Gigault, J., Dassié, É.P., Baudrimont, M., Gourves, P.Y., Amaral-Zettler, L.,
465 Pascal, P.Y., 2022. Metals and metalloids concentrations in three genotypes of pelagic
466 *Sargassum* from the Atlantic Ocean Basin-scale. *Mar. Pollut. Bull.* 178.
467 <https://doi.org/10.1016/j.marpolbul.2022.113564>

468 Clough, B.F., Sim, R.G., Inlet, T., Bay, M., Rivers, I., 1989. Oecologia of mangroves in
469 response to salinity and vapour pressure deficit *. *Oecologia* 79, 38–44.

470 Dassié, E.P., Gourves, P.-Y., Cipolloni, O., Pascal, P.-Y., Baudrimont, M., 2021. First
471 assessment of Atlantic open ocean *Sargassum* spp. metal and metalloid concentrations.
472 *Environ. Sci. Pollut. Res.* <https://doi.org/10.1007/s11356-021-17047-8>

473 Davis, D., Simister, R., Campbell, S., Marston, M., Bose, S., McQueen-Mason, S.J., Gomez,
474 L.D., Gallimore, W.A., Tonon, T., 2021. Biomass composition of the golden tide pelagic
475 seaweeds *Sargassum fluitans* and *S. natans* (morphotypes I and VIII) to inform

476 valorisation pathways. *Sci. Total Environ.* 762, 143134.
477 <https://doi.org/10.1016/j.scitotenv.2020.143134>

478 Davis, T.A., Volesky, B., Vieira, R.H.S.F., 1999. Sargassum seaweed as biosorbent for heavy
479 metals. *Elsevier Sci.* 34, 4270–4278.

480 Dawes, C., Mathieson, A.C., 2008. *The seaweeds of Florida*. Univ. Press Florida, Gainesv.
481 <https://doi.org/10.2989/10220110509485863>

482 Delshab, S., Kouhgard, E., Ramavandi, B., 2016. Data of heavy metals biosorption onto
483 *Sargassum oligocystum* collected from the northern coast of Persian Gulf. *Data Br.* 8,
484 235–241. <https://doi.org/10.1016/j.dib.2016.05.035>

485 Devault, D.A., Massat, F., Baylet, A., Dolique, F., Lopez, P.J., 2021. Arsenic and chlordecone
486 contamination and decontamination toxicokinetics in *Sargassum* sp. *Environ. Sci. Pollut.*
487 *Res.* <https://doi.org/10.1007/s11356-020-12127-7>

488 Devault, D.A., Pierre, R., Marfaing, H., Dolique, F., Lopez, P.J., 2020. Sargassum
489 contamination and consequences for downstream uses: a review. *J. Appl. Phycol.* 33,
490 567–602. <https://doi.org/10.1007/s10811-020-02250-w>

491 Doig, L.E., Liber, K., 2006. Nickel partitioning in formulated and natural freshwater
492 sediments. *Chemosphere* 62, 968–979.
493 <https://doi.org/10.1016/j.chemosphere.2005.06.016>

494 Ender, E., Subirana, M.A., Raab, A., Krupp, E.M., Schaumlöffel, D., Feldmann, J., 2019.
495 Why is NanoSIMS elemental imaging of arsenic in seaweed (: *Laminaria digitata*)
496 important for understanding of arsenic biochemistry in addition to speciation
497 information? *J. Anal. At. Spectrom.* 34, 2295–2302. <https://doi.org/10.1039/c9ja00187e>

498 European Commission, 2019. Official Journal of the European Union, Commission regulation
499 (EU) 2019/1869 of 7 November 2019 amending and correcting annex I to directive
500 2002/32/EC of the European Parliament and of the council as regards maximum levels
501 for certain unde- sirable.

502 Fattorini, D., Notti, A., Regoli, F., 2006. Characterization of arsenic content in marine
503 organisms from temperate, tropical, and polar environments. *Chem. Ecol.* 22, 405–414.
504 <https://doi.org/10.1080/02757540600917328>

505 Feller, I.C., Lovelock, C.E., Berger, U., McKee, K.L., Joye, S.B., Ball, M.C., 2010.
506 Biocomplexity in mangrove ecosystems. *Ann. Rev. Mar. Sci.* 2, 395–417.
507 <https://doi.org/10.1146/annurev.marine.010908.163809>

508 Francesconi, K.A., Edmonds, J.S., 1996. Arsenic and Marine Organisms. *Adv. Inorg. Chem.*
509 44, 147–189. [https://doi.org/10.1016/S0898-8838\(08\)60130-0](https://doi.org/10.1016/S0898-8838(08)60130-0)

510 Gager, L., Lalegerie, F., Connan, S., Stiger-Pouvreau, V., 2021. Marine Algal Derived
511 Phenolic Compounds and their Biological Activities for Medicinal and Cosmetic
512 Applications. *Recent Adv. Micro Macroalgal Process. Food Heal. Perspect.*
513 <https://doi.org/10.1002/9781119542650>

514 Garbinski, L.D., Rosen, B.P., Chen, J., 2019. Pathways of arsenic uptake and efflux. *Environ.*
515 *Int.* 126, 585–597. <https://doi.org/10.1016/j.envint.2019.02.058>

516 García-Sartal, C., 2012. Bioavailability and speciation of arsenic in edible seaweed. Ph.D.
517 thesis. University of Santiago de Compostella, Spain.

518 Gledhiir, M., Buck, K.N., 2012. The organic complexation of iron in the marine environment:
519 A review. *Front. Microbiol.* 3, 1–17. <https://doi.org/10.3389/fmicb.2012.00069>

520 Gobert, T., Gautier, A., Connan, S., Rouget, M.-L., Thibaut, T., Stiger-Pouvreau, V., Waeles,
521 M., 2022. Trace metal content from holopelagic *Sargassum* spp. sampled in the tropical
522 North Atlantic Ocean: Emphasis on spatial variation of arsenic and phosphorus.
523 *Chemosphere* 308, 136186. <https://doi.org/10.1016/j.chemosphere.2022.136186>

524 Gower, J.F.R., King, S.A., 2011. Distribution of floating *Sargassum* in the Gulf of Mexico
525 and the Atlantic ocean mapped using MERIS. *Int. J. Remote Sens.* 32, 1917–1929.
526 <https://doi.org/10.1080/01431161003639660>

527 Guilcher, A., Marec, A., 1978. Le récif-barrière et le lagon du Grand Cul-de-Sac Marin
528 (Guadeloupe, Antilles françaises). *Géomorphologie et sédiments. Oceanol. Acta* 1, 435–
529 444.

530 Guiry, M.D., Guiry, G.M., 2022. World-Wide electronic publication. *Natl. Univ. Ireland.*
531 *Algaebase* 2022.

532 He, J., Chen, J.P., 2014. A comprehensive review on biosorption of heavy metals by algal
533 biomass: Materials, performances, chemistry, and modeling simulation tools. *Bioresour.*
534 *Technol.* 160, 67–78. <https://doi.org/10.1016/j.biortech.2014.01.068>

535 Holloway, C.J., Santos, I.R., Tait, D.R., Sanders, C.J., Rose, A.L., Schnetger, B., Brumsack,
536 H.J., Macklin, P.A., Sippo, J.Z., Maher, D.T., 2016. Manganese and iron release from
537 mangrove porewaters: A significant component of oceanic budgets? *Mar. Chem.* 184,
538 43–52. <https://doi.org/10.1016/j.marchem.2016.05.013>

539 Howard, A.G., Comber, S.D.W., Kifle, D., Antai, E.E., Purdie, D.A., 1995. Arsenic
540 speciation and seasonal changes in nutrient availability and micro-plankton abundance in
541 southampton water, U.K. *Estuar. Coast. Shelf Sci.* 40, 435–450.
542 <https://doi.org/10.1006/ecss.1995.0030>

543 Johns, E.M., Lumpkin, R., Putman, N.F., Smith, R.H., Muller-Karger, F.E., T. Rueda-Roa,

544 D., Hu, C., Wang, M., Brooks, M.T., Gramer, L.J., Werner, F.E., 2020. The
545 establishment of a pelagic Sargassum population in the tropical Atlantic: Biological
546 consequences of a basin-scale long distance dispersal event. *Prog. Oceanogr.* 182,
547 102269. <https://doi.org/10.1016/j.pocean.2020.102269>

548 Khotimchenko, Y.S., Kovalev, V. V., Savchenko, O. V., Ziganshina, O.A., 2001. Physical-
549 Chemical Properties, Physiological Activity, and Usage of Alginates, the
550 Polysaccharides of Brown Algae. *Russ. J. Mar. Biol.* 27.
551 <https://doi.org/10.1023/A:1013851022276>

552 Koivikko, R., Lopenen, J., Honkanen, T., Jormalainen, V., 2005. Contents of soluble, cell-
553 wall-bound and exuded phlorotannins in the brown alga *Fucus vesiculosus*, with
554 implications on their ecological functions. *J. Chem. Ecol.* 31, 195–212.
555 <https://doi.org/10.1007/s10886-005-0984-2>

556 Laffoley, D. d'A., Roe, H.S.J., Angel, M. V, Ardon, J., Bates, N.R., Boyd, I.L., Brooke, S.,
557 Buck, K.N., Carlson, C. a, Causey, B., Conte, M.H., Christiansen, S., Cleary, J.,
558 Donnelly, J., Earle, S. a, Edwards, R., Gjerde, K.M., Giovannoni, S.J., Gulick, S.,
559 Gollock, M., Hallett, J., Halpin, P., Hnel, R., Hemphill, A., Johnson, R.J., Knap, a H.,
560 Lomas, M.W., McKenna, S. a, Miller, M.J., Miller, P.I., Ming, F.W., Moffitt, R., Nelson,
561 N.B., Parson, L., Peters, a J., Pitt, J., Rouja, P., Roberts, J., Seigel, D. a, Siuda, a N.S.,
562 Steinberg, D.K., Stevenson, A., Sumaila, V.R., Swartz, W., Thorrold, S., Trott, T.M.,
563 Vats, V., 2011. The protection and management of the Sargasso Sea: The golden floating
564 rainforest of the Atlantic Ocean. Summary Science and Supporting Evidence Case.,
565 Sargasso Sea Alliance: The golden floating rainforest of the Atlantic Ocean.

566 Langin, K., 2018. Seaweed masses assault Caribbean islands. *Science* (80-.). 360, 1157–
567 1158. <https://doi.org/10.1126/science.360.6394.1157>

568 Lapointe, B., 1995. A comparison of nutrient-limited productivity in *Sargassum natans* from
569 neritic vs. oceanic waters of the western North Atlantic Ocean. *Limnol. Oceanogr.*
570 <https://doi.org/10.2307/2838178>

571 López Miranda, J.L., Celis, L.B., Estévez, M., Chávez, V., van Tussenbroek, B.I., Uribe-
572 Martínez, A., Cuevas, E., Rosillo Pantoja, I., Masia, L., Cauich-Kantun, C., Silva, R.,
573 2021. Commercial Potential of Pelagic *Sargassum* spp. in Mexico. *Front. Mar. Sci.* 8.
574 <https://doi.org/10.3389/fmars.2021.768470>

575 Mader, P., Salomons, W., Forstner, U., 1995. Heavy metals : problems and solutions, Berlin,
576 Springer-Verlag, Environmental science. Springer-Verlag, Berlin.

577 Mamun, M.A. Al, Omori, Y., Papry, R.I., Kosugi, C., Miki, O., 2019. Bioaccumulation and

578 biotransformation of arsenic by the brown macroalga *Sargassum patens* C. Agardh in
579 seawater : effects of phosphate and iron ions 2669–2685.

580 Maurer, A.S., Gross, K., Stapleton, S.P., 2022. Beached *Sargassum* alters sand thermal
581 environments: Implications for incubating sea turtle eggs. *J. Exp. Mar. Bio. Ecol.* 546,
582 151650. <https://doi.org/10.1016/j.jembe.2021.151650>

583 Maurer, A.S., Neef, E. De, Stapleton, S., 2015. *Sargassum* accumulation may spell trouble for
584 nesting sea turtles. *Front. Ecol. Environ.* 13, 394–395.

585 Milledge, J., Harvey, P., 2016. Golden Tides: Problem or Golden Opportunity? The
586 Valorisation of *Sargassum* from Beach Inundations. *J. Mar. Sci. Eng. Rev.* 4, 60.
587 <https://doi.org/10.3390/jmse4030060>

588 Narancic, B., Wolfe, B.B., Pienitz, R., Meyer, H., Lamhonwah, D., 2017. Landscape-gradient
589 assessment of thermokarst lake hydrology using water isotope tracers. *J. Hydrol.* 545,
590 327–338. <https://doi.org/10.1016/j.jhydrol.2016.11.028>

591 Neff, J., 1997. Ecotoxicology of Arsenic in the marine environment. *Environ. Toxicol. Chem.*
592 16, 917–927.

593 Oviatt, C.A., Huizenga, K., Rogers, C.S., Miller, W.J., 2019. What nutrient sources support
594 anomalous growth and the recent *sargassum* mass stranding on Caribbean beaches? A
595 review. *Mar. Pollut. Bull.* 145, 517–525.
596 <https://doi.org/10.1016/j.marpolbul.2019.06.049>

597 Oyesiku, O.O., Egunyomi, A., 2014. Identification and chemical studies of pelagic masses of
598 *Sargassum natans* (Linnaeus) Gaillon and *S. fluitans* (Borgesen) Borgesen (brown
599 algae), found offshore in Ondo State, Nigeria. *African J. Biotechnol.* 13, 1188–1193.
600 <https://doi.org/10.5897/ajb2013.12335>

601 Plouguerné, E., Le Lann, K., Connan, S., Jechoux, G., Deslandes, E., Stiger-Pouvreau, V.,
602 2006. Spatial and seasonal variation in density, reproductive status, length and phenolic
603 content of the invasive brown macroalga *Sargassum muticum* (Yendo) Fensholt along
604 the coast of Western Brittany (France). *Aquat. Bot.* 85, 337–344.
605 <https://doi.org/10.1016/j.aquabot.2006.06.011>

606 Ragan, M.A., Craigie, J.S., 1976. Physodes and the phenolic compounds of brown algae.
607 Isolation and characterization of phloroglucinol polymers from *Fucus vesiculosus* (L.).
608 *Can. J. Biochem.* 54, 66–73. <https://doi.org/10.1139/o76-011>

609 Reiffenstein, R., Hulbert, W., Roth, S., 1992. Toxicology of Hydrogen sulfide. *Pharmacol*
610 *Toxicol* 32, 109–134. <https://doi.org/10.1097/00000542-197308000-00013>

611 Resiere, D., Valentino, R., Nevière, R., Banydeen, R., Gueye, P., Florentin, J., Cabié, A.,

612 Lebrun, T., Mégarbane, B., Guerrier, G., Mehdaoui, H., 2018. Sargassum seaweed on
613 Caribbean islands: an international public health concern. *Lancet* 392, 2691.
614 [https://doi.org/10.1016/S0140-6736\(18\)32777-6](https://doi.org/10.1016/S0140-6736(18)32777-6)

615 Rezaei, M., Kafaei, R., Mahmoodi, M., Sanati, A.M., Vakilabadi, D.R., Arfaenia, H.,
616 Dobaradaran, S., Sorial, G.A., Ramavandi, B., Boffito, D.C., 2021. Heavy metals
617 concentration in mangrove tissues and associated sediments and seawater from the north
618 coast of Persian Gulf, Iran: Ecological and health risk assessment. *Environ.*
619 *Nanotechnology, Monit. Manag.* 15, 2023. <https://doi.org/10.1016/j.enmm.2021.100456>

620 Rhein-Knudsen, N., Ale, M.T., Ajallouei, F., Meyer, A.S., 2017. Characterization of
621 alginates from Ghanaian brown seaweeds: *Sargassum* spp. and *Padina* spp. *Food*
622 *Hydrocoll.* 71, 236–244. <https://doi.org/10.1016/j.foodhyd.2017.05.016>

623 Robledo, D., Vázquez-delfín, E., Freile-pelegrín, Y., 2021. Challenges and Opportunities in
624 Relation to Sargassum Events Along the Caribbean Sea 8, 1–13.
625 <https://doi.org/10.3389/fmars.2021.699664>

626 Rodríguez-Martínez, R.E., Medina-Valmaseda, A.E., Blanchon, P., Monroy-Velázquez, L.
627 V., Almazán-Becerril, A., Delgado-Pech, B., Vásquez-Yeomans, L., Francisco, V.,
628 García-Rivas, M.C., 2019. Faunal mortality associated with massive beaching and
629 decomposition of pelagic *Sargassum*. *Mar. Pollut. Bull.* 146, 201–205.
630 <https://doi.org/10.1016/j.marpolbul.2019.06.015>

631 Rodríguez-Martínez, R.E., Roy, P.D., Torrescano-Valle, N., Cabanillas-Terán, N., Carrillo-
632 Domínguez, S., Collado-Vides, L., García-Sánchez, M., Tussenbroek, B.I. van, 2020.
633 Element concentrations in pelagic *Sargassum* along the Mexican Caribbean coast in
634 2018-2019. *Peer J* 10, 14.

635 Ross, S.W., Casazza, T.L., 2008. Fishes associated with pelagic *Sargassum* and open water
636 lacking *Sargassum* in the Gulf Stream off North Carolina. *Fish. Bull.* 106, 348–363.

637 Saberzadeh Sarvestani, F., Esmaili, H., Ramavandi, B., 2016. Modification of *Sargassum*
638 *angustifolium* by molybdate during a facile cultivation for high-rate phosphate removal
639 from wastewater: structural characterization and adsorptive behavior. *3 Biotech* 6, 1–12.
640 <https://doi.org/10.1007/s13205-016-0570-z>

641 Sadeghi, S.A.T., Kamali, A.A., Kabirifard, A.M., 2014. Determination of Heavy Metals in
642 *Sargassum angustifolium* Marine Alga of South West Coasts of Iran for Using in Animal
643 Nutrition. *Env. Pharmacol. Life Sci* 3, 261–265.

644 Sanders, J.G., Windom, H.L., 1980. The uptake and reduction of arsenic species by marine
645 algae. *Estuar. Coast. Mar. Sci.* 10, 555–567. <https://doi.org/10.1016/S0302->

646 3524(80)80075-2

647 Schoenwaelder, M.E.A., Clayton, M.N., 1999. The presence of phenolic compounds in
648 isolated cell walls of brown algae. *Phycologia* 38, 161–166.

649 <https://doi.org/10.2216/i0031-8884-38-3-161.1>

650 Sissini, M.N., De Barros Barreto, M.B.B., Szechy, M.T.M., De Lucena, M.B., Oliveira, M.C.,

651 Gower, J., Liu, G., De Oliveira Bastos, E., Milstein, D., Gusmão, F., Martinelli-Filho,

652 J.E., Alves-Lima, C., Colepicolo, P., Ameka, G., De Graftjohnson, K., Gouvea, L.,

653 Torrano-Silva, B., Nauer, F., Marcos De Castronunes, J., Bonomibarufi, J., Rörig, L.,

654 Riosmena-Rodríguez, R., Mello, T.J., Lotufo, L.V.C., Horta, P.A., 2017. The floating

655 *Sargassum* (Phaeophyceae) of the South Atlantic Ocean - Likely scenarios. *Phycologia*

656 56, 321–328. <https://doi.org/10.2216/16-92.1>

657 Széchy, M.T.M., Guedes, P.M., Baeta-Neves, M.H., Oliveira, E.N., 2012. Verification of

658 *Sargassum natans* (Linnaeus) Gaillon (Heterokontophyta: Phaeophyceae) from the

659 Sargasso Sea off the coast of Brazil, western Atlantic Ocean. *Check List* 8, 638–641.

660 <https://doi.org/10.15560/8.4.638>

661 van Tussenbroek, B.I., Hernández Arana, H.A., Rodríguez-Martínez, R.E., Espinoza-Avalos,

662 J., Canizales-Flores, H.M., González-Godoy, C.E., Barba-Santos, M.G., Vega-Zepeda,

663 A., Collado-Vides, L., 2017. Severe impacts of brown tides caused by *Sargassum* spp. on

664 near-shore Caribbean seagrass communities. *Mar. Pollut. Bull.* 122, 272–281.

665 <https://doi.org/10.1016/j.marpolbul.2017.06.057>

666 Velasco-González, O., Echavarría-Almeida, S., de León, A.S.D., and Casas-Valdez, 2013.

667 Uso del alga marina *Sargassum* spp. adicionada a la harina de trigo para preparar galletas

668 alimenticias para consumo humano. *Bioagro* 25, 189–194.

669 Vieira, R.H.S.F., Volesky, B., 2000. Biosorption: a solution to pollution? *Int. Microbiol.* 3,

670 17–24. <https://doi.org/10.2436/im.v3i1.9237>

671 Volesky, B., Holan, Z.R., 1995. Biosorption of Heavy Metals. *Biotechnol. Prog.* 11, 235–250.

672 <https://doi.org/10.1021/bp00033a001>

673 Wang, M., Hu, C., Barnes, B.B., Mitchum, G., Lapointe, B., Montoya, J.P., 2019. The great

674 Atlantic *Sargassum* belt. *Science* (80-.). 364, 83–87.

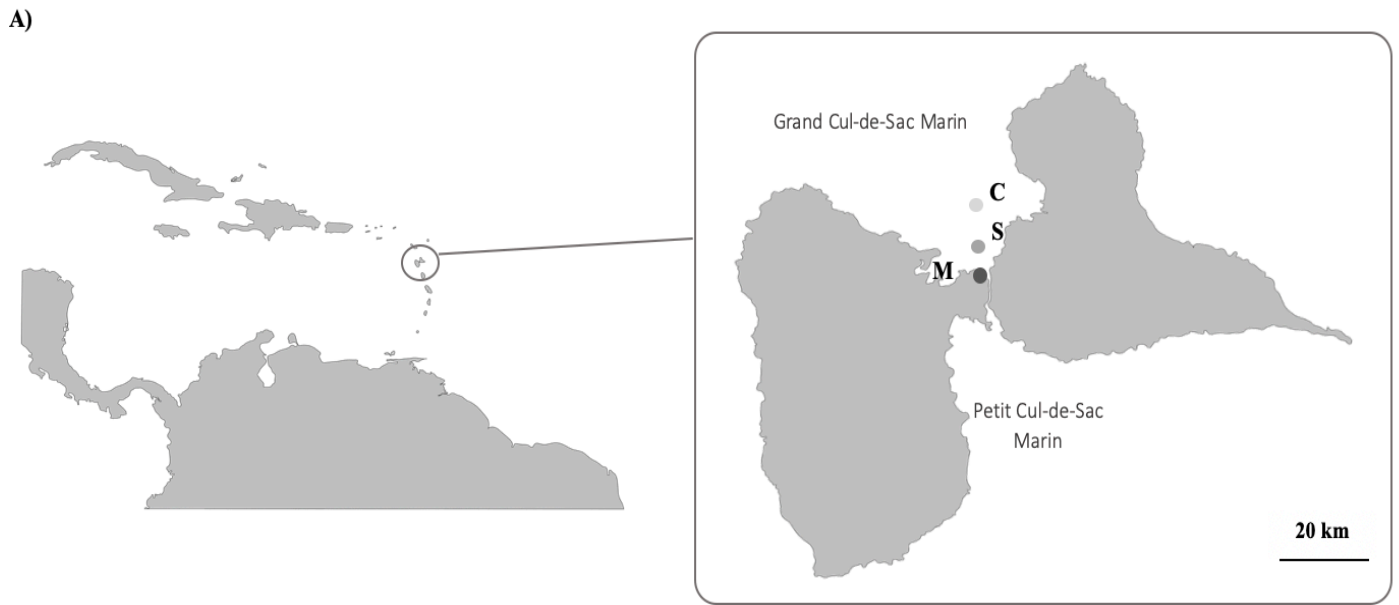
675 <https://doi.org/10.1126/science.aaw7912>

676 Zubia, M., Fabre, M.S., Kerjean, V., Lann, K. Le, Stiger-Pouvreau, V., Fauchon, M.,

677 Deslandes, E., 2009. Antioxidant and antitumoural activities of some Phaeophyta from

678 Brittany coasts. *Food Chem.* 116, 693–701.

679 <https://doi.org/10.1016/j.foodchem.2009.03.025>



B)

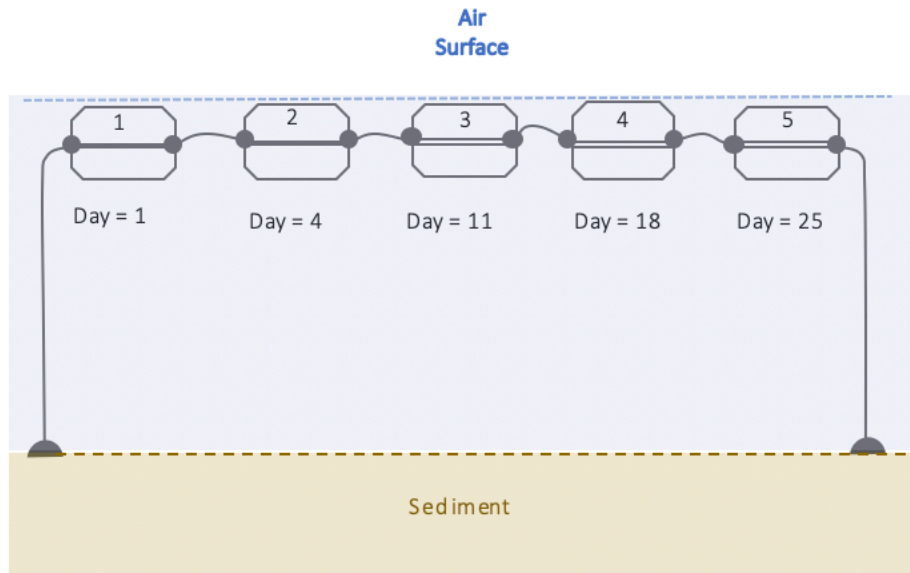
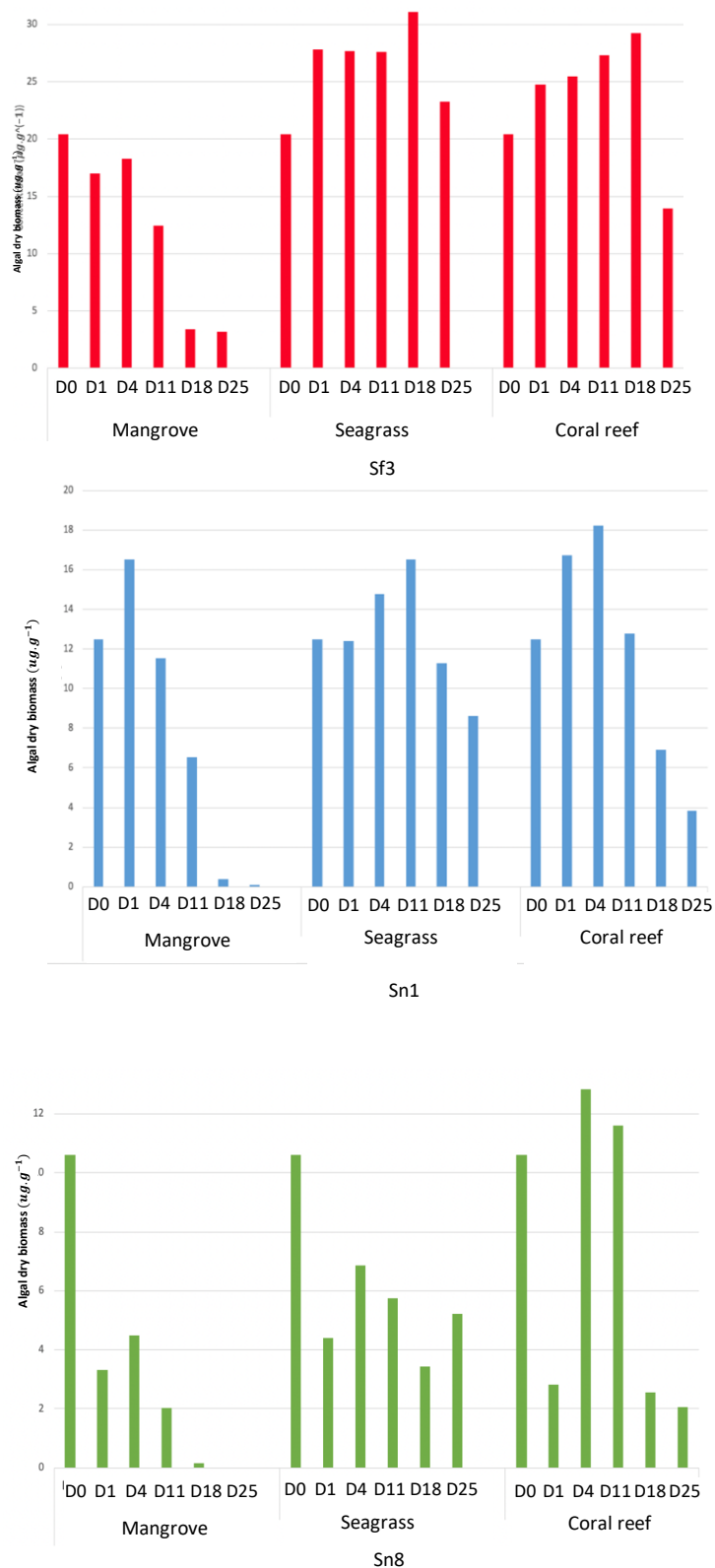


Figure 1 Sampling site and experiments setting up. **Figure 1.A** Location of the sampling sites experimentation: CR (coral reef) ($8^{\circ}02'N$; $-47^{\circ}07'W$), H (seagrass meadow) ($6^{\circ}87'N$; $-34^{\circ}42'W$), M (mangrove) ($6^{\circ}98'N$; $-31^{\circ}80'W$) of the prototype experimentation 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>
Control Mangrove	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
Seagrass	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
Coral reef	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
IAEA413 recovery rate (%SD)			101,29 ± 4,66	96,76±44,39		97,66±7,33
DOLT-5 recovery rate (%SD)			99,93±0,58	91,21±24,59	100,12±0,61	99,91±2,36
TORT-3 recovery rate (%SD)			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)

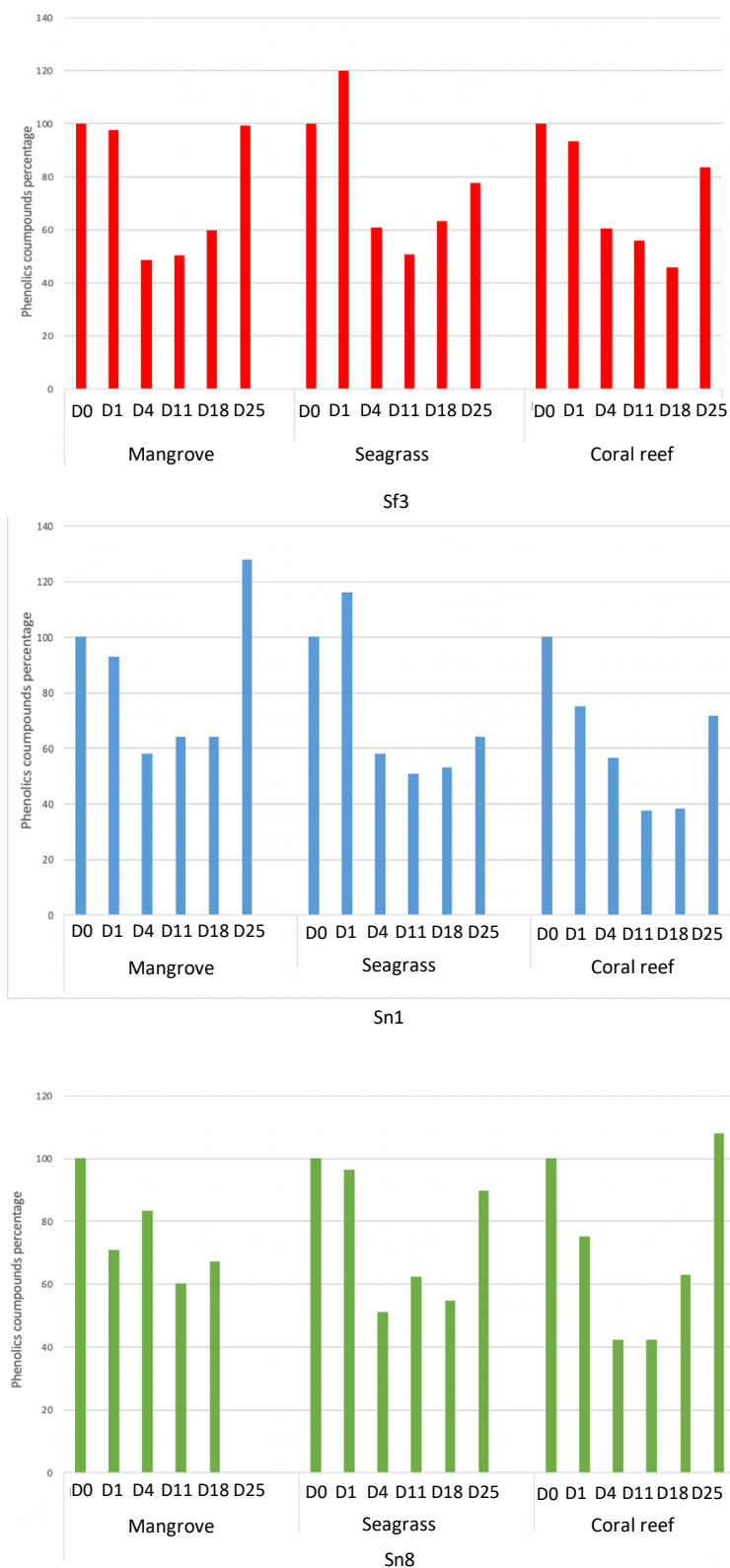


Fig 2. Algal dry biomass in $\mu\text{g.g}^{-1}$ (Fig 2.A) and phenolics content (%) (Fig 2.B) of *Sargassum* algae collected from the three different habitats (coral reef, seagrass and mangrove) for the three morphotypes of *Sargassum* sp. (*S. fluitans* III (SF3); *S. natans* I (SN1) and *S. natans*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

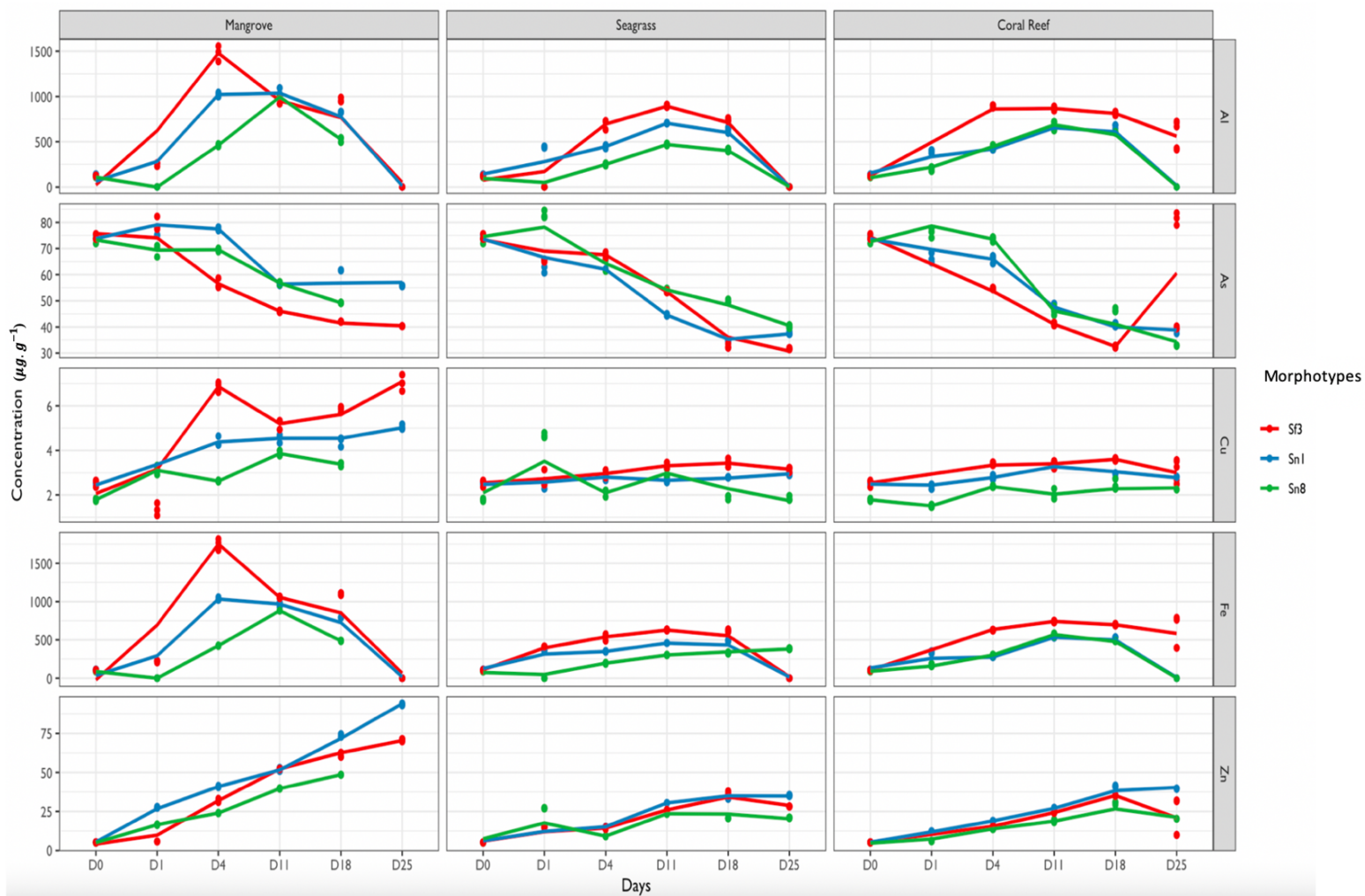


Fig 3. Temporal variability of metal concentrations. Concentrations in Al, As, Cu, Fe and Zn ($\mu\text{g.g}^{-1}$) in *Sargassum* algae collected from the three different habitats (coral reef, seagrass and mangrove) for the three morphotypes of *Sargassum* spp. (*S. fluitans* III (Sf3); *S. natans*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

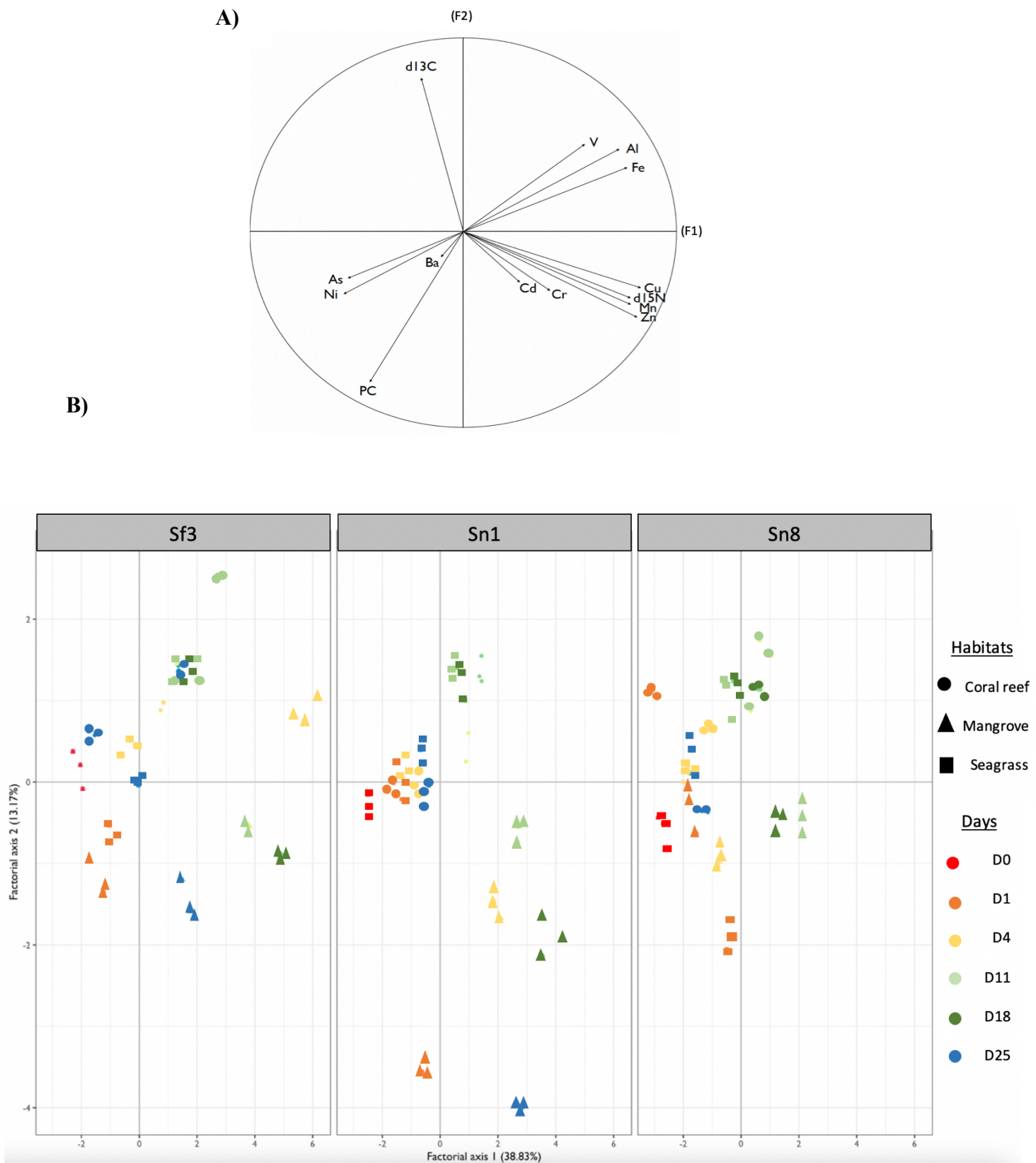
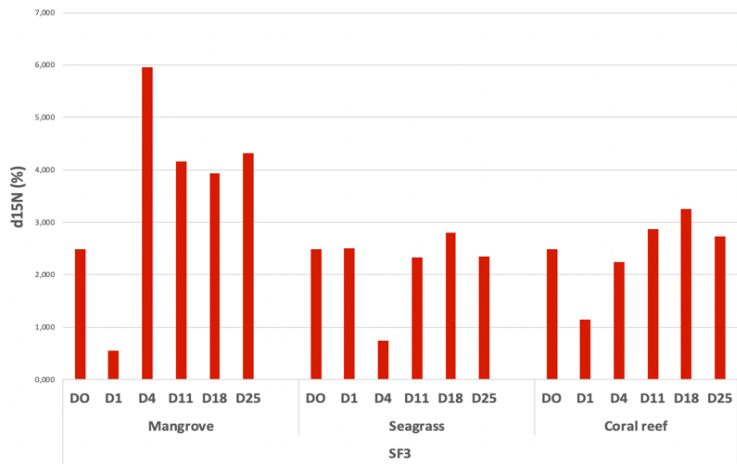


Fig 4. Principal Component Analyses (PCA) showing variables (Fig.4 A) and Temporal Principal Component Analyses (Fig.4 B). F1 (38.82%) and F2 (13.17%) represents the relationship in *Sargassum* sp. between all the metallic elements (As; Ni; Ba; Cd; Cr; Zn; Cu; Mn, Fe; Al and V), the isotopic signature ($\delta^{15}N$ 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)

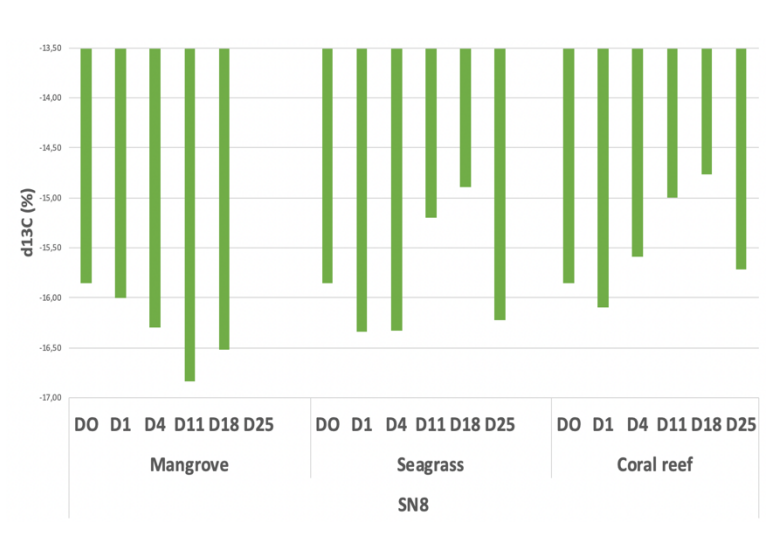
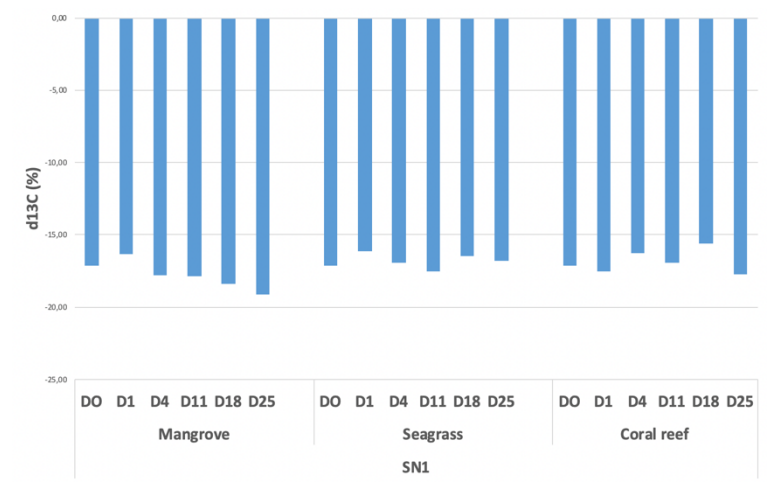
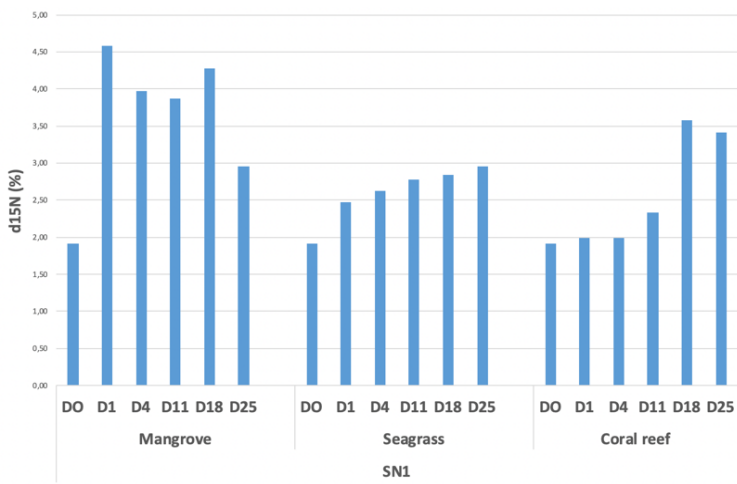
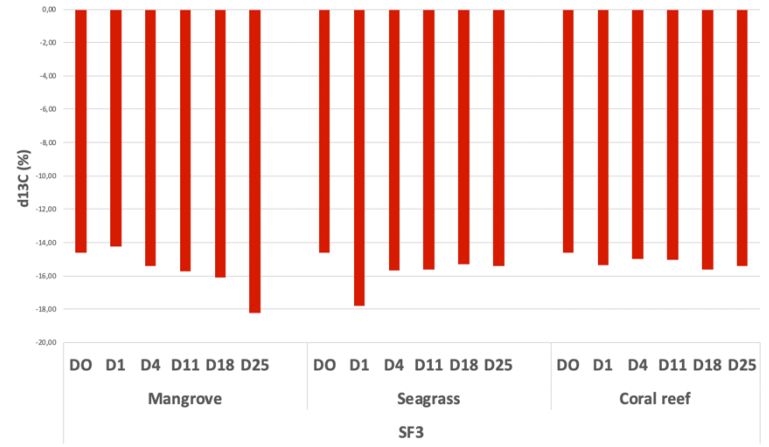


Fig (supplement). Isotopic signature for $\delta^{15}N$ (A) and for $\delta^{13}C$ (B) of *Sargassum* algae collected from the three different habitats (coral reef, seagrass, mangrove) for the three morphotypes of *Sargassum* spp. (*S. fluitans* III (SF3); *S. natans* I (SN1) and *S. natans* VIII (SN8))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

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