Chemical contamination along the Mediterranean French coast using *Posidonia oceanica* (L.) Delile above-ground tissues: a multiple trace element study

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ABSTRACT

Levels of Be, Al, V, Mn, Co, As, Se, Mo, Ag, Sn, Sb, Bi as well as of Cr, Fe, Ni, Cu, Zn, Cd and Pb in *Posidonia oceanica* (L.) Delile from the Mediterranean French coast were analysed using DRC ICP-MS. The first twelve elements have not been well studied and can be considered to be potential pollutants as a result of potentially increased levels resulting from anthropogenic activities. Spatial variation and/or compartmentalization were found for all trace elements. Except for Al, Cr, Fe, Cu and Ag, most trace elements were preferentially accumulated in photosynthetic tissues, suggesting uptake from the water column. Moreover, for Be, V, Mn, Co, Ni, As, Mo, Sb, Sn and Pb, adult leaves had higher levels than intermediate leaves, suggesting low kinetics of accumulation. Levels in the third intermediate leaf were representative of the average levels of the integral shoot, and thus can be used alone in chemical biomonitoring. For most of the twelve little-studied trace elements, the background levels of the northwestern Mediterranean Sea can be measured, and their spatial variation can be related to anthropogenic activities. Levels of the seven widely studied trace elements seem to decrease or stabilize over time, probably due to their reduced anthropogenic use. These observations show that *P. oceanica* is a sensitive bioindicator for the monitoring of chemical contamination of a large number of trace elements.

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1. Introduction

Posidonia oceanica (L.) Delile, the endemic seagrass of the Mediterranean, forms monospecific meadows from the surface to depths of 40 m (Boudouresque and Meinesz, 1982). They cover large areas in clear coastal regions estimated to be between 2.5 and 5 million hectares (Pasqualini et al., 1998). They constitute an engineering ecosystem playing major ecological, geological and economic roles, but are sensitive to human disturbances such as coastal development, pollution, high water turbidity and trawling (Boudouresque et al., 2006). In 2000, *P. oceanica* was selected as a Biological Quality Element (BQE; Med-GIG, 2009) representative of aquatic Mediterranean angiosperms for monitoring the ecological status of coastal waters under the Water Framework Directive (EC, 2000). Therefore, many indices based on physiological, morphological and/or structural descriptors of *P. oceanica* have been developed, e.g. POMI (Romero et al., 2007a,b), PREI (Gobert et al., 2009), BiPo (Lopez y Royo et al., 2010), etc.

Metals are regarded as serious pollutants of the aquatic environment because of their toxicity, their persistence, their difficulty in biodegrading and their tendency to concentrate in aquatic organisms (Ikem and Egiebor, 2005). Many metalloids (As, Sb, etc.) and some non-metals (Se, etc.) can also be considered as serious pollutants of the aquatic environment. However, some of these are needed for seagrass subsistence (micronutrients) such as Fe, Mn, Co, Ni, Cu and Zn (Babula et al., 2008). In agreement with Duffus (2002), we use the term “trace element” (TE) for those elements that are present in trace amounts in the environment.

Levels of some TEs (Cd, Hg, Cu, Cr, Pb, Zn, Fe and Ni) have been largely studied in *P. oceanica* tissues (see Supplementary Table) and both below- and above-ground tissues have been analysed. In particular, *P. oceanica* leaves can give an indication of TE levels in seawater over a short period with accuracy (Pergent-Martini et al., 2005). Furthermore, Romero et al. (2007b) suggested that the third intermediate leaf alone (bearing few epiphytes and between 100 and 150 days old) can be used for TE monitoring instead of the integral shoot.

The development of new equipment and techniques now allows us to measure many TEs found at very low levels (Wieser and Schwieters, 2005); moreover, recent technological and industrial developments still modify levels of TEs naturally present in the

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environment (Ravindra et al., 2004). Environmental quantification of other previously unstudied potential pollutants is henceforth now possible and relevant: (i) V is used in many fields: railway, aerospace, catalysis, etc. It is found in large amounts in hydrocarbon fuels, the main source of this pollutant, and it can be used as a tracer for petrol pollutions such as oil spills (Amiard et al., 2003); (ii) Sb is a component of many alloys, and is often used as fire-proofing additive. This TE is released in large amounts during its extraction, smelting, as well as during waste incineration and fossil energy combustion (Filella et al., 2002); (iii) Bi is mainly used in specialized industry; Karlsson et al. (2007) determined that the major worldwide atmospheric deposition of Bi took place after the Second World War.

The objectives of this study were firstly to measure levels of TEs that were little or never studied in *P. oceanica* tissues (Be, Al, V, Mn, Co, As, Se, Mo, Ag, Sn, Sb and Bi) along the Mediterranean French coast, to examine compartmentalization and spatial variation, and to evaluate the potential use of *P. oceanica* above-ground tissues as bioindicators. Secondly, we investigated spatial and temporal variations of TEs classically investigated (Cd, Cu, Cr, Pb, Zn, Fe and Ni), as well as their compartmentalization. Finally, the ability to use the *P. oceanica* third intermediate leaf instead of the integral shoot for the biomonitoring of these nineteen TEs was investigated.

2. Materials and methods

2.1. Sampling location and design

In April 2007, 15 shoots of *P. oceanica*, each spaced apart 5 m, were sampled at a depth of 15 ± 1 m at 18 sites located along the Provence-Alpes-Côte d'Azur (PACA) and Corsican coasts (Fig. 1). Collected samples were placed in acid-rinsed sample bags and stored at -28°C .

2.2. Sample treatment

For each site, *P. oceanica* shoots were dissected according to the method proposed by Giraud (1979). Epiphytes were scraped from leaves using a ceramic scalpel blade. Furthermore, each shoot was sorted and recorded as follows: third intermediate leaves (3IL), other intermediate leaves (OIL), blades of adult leaves (BAL) and sheaths of adult leaves (SAL). Sorted tissues were lyophilized (BenchTop 3L, VirTis Company Inc.), weighed and then grouped together (by site) to constitute pools of dried tissues weighing a minimum of 300 mg (mostly 5 pools, sometimes down to 3 for SAL). These pools were ground with liquid nitrogen in an agate mortar and then re-lyophilized to eliminate condensed ambient water vapour. Dried powders were finally mineralized in Teflon bombs using a closed microwave digestion labstation (Ethos D, Milestone Inc.). Two digestion procedures were performed: a nitric acid mineralization ($\text{HNO}_3/\text{H}_2\text{O}_2$; all TEs except Sn and Sb) and an aqua regia mineralization (HNO_3/HCl ; Sn and Sb). Acids and hydrogen peroxide (suprapure grade) were purchased from Merck. Finally, mineralisats were diluted to an appropriate volume of 50 cm^3 .

2.3. Trace element analysis

Trace element levels were determined by inductively coupled plasma mass spectrometry (ICP-MS) using dynamic reaction cell (DRC) technology (ICP-MS ELAN DRC II, PerkinElmer Inc.). This instrument uses ion-molecule reactions to overcome spectral overlaps and requires selection of the appropriate reaction gas (Olesik and Jones, 2006): no reaction gas in standard mode (for ^9Be , ^{95}Mo , ^{107}Ag , ^{111}Cd , ^{118}Sn , ^{121}Sb , ^{208}Pb and ^{209}Bi), NH_3 (for ^{27}Al , ^{51}V , ^{52}Cr , ^{54}Fe , ^{55}Mn , ^{59}Co , ^{60}Ni and ^{66}Zn) or H_2 (for ^{75}As and ^{78}Se) in DRC

modes. Analytical accuracy was checked by analysing certified reference materials (Table 1A): BCR 60 (*Lagarosiphon major*), BCR 62 (*Olea europaea*), GBW 07603 (brush branch and leaves) and V463 (maize).

2.4. Statistical analysis

General trends of TE levels (compartmentalization and shoot average levels, Table 1B) were calculated for all sites together, excluding extreme values: only values between the 10th and 90th percentiles were included. Each replicate (Fig. 2 *Posidonia oceanica* compartmentalization and Table 1B tissue trends) represents the TE level of an individual pooled subsample, obtained by pooling the same tissues from 3 shoots (up to 5 for SAL) from the same site. TE levels measured in the 4 compartments of *P. oceanica* were balanced by their respective dry weight to calculate shoot TE levels (Table 1B shoot trends, Table 1C). For each element, detection decision (L_C), detection limit (L_D) and quantification limit (L_Q) were calculated according to Currie (IUPAC et al., 1998; Currie, 1999) or Grinzaid et al. (1977), depending on their specific blank distribution. One-way analysis of variance (ANOVA) followed by Tukey HSD pairwise comparison test of means with unequal n 's ($p < 0.05$) were performed (Fig. 2 and Table 1B tissue trends), after testing for homogeneity of variances (Levene test) on raw or log-transformed data. Non-parametric analysis of variance (Kruskal–Wallis test) was only performed for V, Sb and Pb (Table 1B; assumptions prior to unbalanced ANOVAs not encountered), followed by Dunn pairwise comparison test of means ($p < 0.05$) (STATISTICA 8.0, StatSoft Inc.).

3. Results and discussion

Based on general trends of average levels found in shoots (Table 1B), TE levels decreased in the following order: Zn, Fe, Al > Mn > Ni > Cu > V > Co, Cd, Pb, Mo, As > Ag > Cr, Se, Sb > Sn > Bi, Be. This sequence completes and confirms the sequence commonly observed in *P. oceanica*: Zn > Ni > Cu > Cd, Pb > Cr (Pergent-Martini, 1994; Warnau et al., 1995; Schlacher-Hoenlinger and Schlacher, 1998; Campanella et al., 2001; Conti et al., 2010).

3.1. *Posidonia oceanica* compartmentalization

General trends of compartmentalization are reported in Table 1B. Additionally, compartmentalization of V, Zn, Cr and Cu are shown for the four contrasted sites being compared, with respect to their TE levels (Fig. 2). Compartmentalization profiles of the other TEs are similar to one of these four characteristic profiles.

Most TEs were preferentially concentrated in photosynthetic tissues (i.e. 3IL, OIL and BAL) rather than in non-photosynthetic tissue (SAL): V, Mn, Co, Ni, Zn, As, Se, Mo, Cd, Sb, Pb and Bi (levels twice as high, except for As and Se). Furthermore, Mn, Co, Ni, As, Mo, Sb, Pb, Bi, and particularly V, were present in higher levels in BAL (e.g. V in Fig. 2a), contrary to Zn, Se and Cd, present in similar levels in all photosynthetic tissues (e.g. Zn in Fig. 2b), regardless of site. In the particular case of Be, the general trend of compartmentalization was not confirmed when observing sites independently from each other. For Sn, a signal could be clearly measured only in BAL. On the other hand, Al, Fe, Ag and Cu were preferentially accumulated in non-photosynthetic tissues. More precisely, Al, Fe and Ag, as well as Cr levels were systematically higher in SAL only in sites where the highest levels were recorded (e.g. Cr in Fig. 2c). Concerning Cu, levels in SAL were systematically higher than in other tissues, but differences were quite small (Fig. 2d).

These findings are in agreement with previous studies: Pergent-Martini (1994) for Cr, Fe, Cu, Zn, Cd and Pb; Campanella et al. (2001) for Cr, Zn, Cd and Pb, but not for Cu; Kljakovic-Gaspic et al. (2004)

Table 1
(A) Evaluation of analytical accuracy through certified reference materials (CRM). (B) General trends of *Posidonia oceanica* trace element levels (tissue compartmentalization [$n=54-74$] and shoot concentrations [$n=217$]). (C) Spatial variation of trace element levels in *Posidonia oceanica* shoots [$n=15$ for each site]. Levels are expressed as mean $\pm$ standard deviation in $\mu\text{g g}_{\text{DW}}^{-1}$; letters represent significant differences between tissues ($p < 0.05$); *, **, struck-through values and ND represent concentrations $< L_Q$, $< L_D$, $< L_C$ and not detected, respectively; italic values represent indicative values of CRM; n represents number of replicates.

	Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn										
A: CRM																				
CRM values
BCR 60		4180 ± 120			1759 ± 51			40.0	51.2 ± 1.9	313 ± 8										
BCR 62		450 ± 20			57 ± 2			8.0	46.6 ± 1.8	16 ± 1										
GBW 07603	0.051 ± 0.004	2000 ± 300	2.4 ± 0.40	2.60 ± 0.20	61 ± 5	1070 ± 57	0.41 ± 0.05	1.7 ± 0.3	6.6 ± 0.8	55 ± 4										
V463		172 ± 3		3.37 ± 0.61	25 ± 1	366 ± 25	0.18 ± 0.06	3.4 ± 0.2	4.7 ± 0.5	61 ± 1										
Our values																				
BCR 60 (n = 7–22)		1572 ± 153			1566 ± 87			43.3 ± 1.5	51.0 ± 6.4	285 ± 13										
BCR 62 (n = 15–19)		368 ± 27			53 ± 2			7.8 ± 0.5	44.4 ± 4.2	15 ± 1										
GBW 07603 (n = 10–28)	0.042 ± 0.012	1081 ± 117	1.8 ± 0.18	1.65 ± 0.16	61 ± 2	885 ± 51	0.62 ± 0.04	7.3 ± 0.3	7.0 ± 0.3	54 ± 3										
V463 (n = 15–28)		121 ± 14		1.64 ± 0.28	23 ± 1	318 ± 27	0.14 ± 0.01	3.0 ± 0.2	4.1 ± 0.1	52 ± 3										
	Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn										
B: Plant tissues																				
3IL (trends; n = 72–74)	**ab	0.0063 ± 0.0026	b	84 ± 37	b	6.5 ± 4.5	ab	0.29 ± 0.10	a	61 ± 10	a	98 ± 32	a	2.59 ± 0.45	b	31 ± 4	b	12.8 ± 3.3	a	107 ± 22
OIL (trends; n = 73)	**ab	0.0065 ± 0.0024	ab	81 ± 28	b	5.6 ± 4.2	ab	0.23 ± 0.08	a	54 ± 9	a	92 ± 26	a	2.21 ± 0.42	ab	24 ± 2	ab	13.2 ± 3.6	a	98 ± 22
BAL (trends; n = 71–73)	*a	0.0097 ± 0.0027	b	90 ± 38	a	9.9 ± 7.1	a	0.35 ± 0.09	a	76 ± 14	a	99 ± 27	a	3.42 ± 0.71	a	39 ± 5	b	11.4 ± 3.5	a	107 ± 22
SAL (trends; n = 54–55)	b	0.0058 ± 0.0026	a	151 ± 66	c	1.2 ± 0.6	b	0.32 ± 0.24	b	14 ± 3	a	126 ± 54	b	0.28 ± 0.04	c	13 ± 2	a	16.8 ± 4.4	b	34 ± 8
Shoot (trends; n = 217)	*	0.0076 ± 0.0018		96 ± 33		7.2 ± 4.9		0.30 ± 0.09		60 ± 10		102 ± 29		2.56 ± 0.47		30 ± 3		12.8 ± 3.4		98 ± 20
	Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn										
C: Sites																				
PACA																				
Ensues (1)	*	0.0094 ± 0.0015		118 ± 18		9.6 ± 2.6		0.37 ± 0.04		64 ± 2		139 ± 14		2.38 ± 0.12		30 ± 2		13.0 ± 0.4		105 ± 5
La Vesse (2)	*	0.0079 ± 0.0022		114 ± 29		11.8 ± 3.2		0.33 ± 0.05		65 ± 4		122 ± 14		2.81 ± 0.15		32 ± 2		19.8 ± 0.6		157 ± 7
Corbière (3)	*	0.0095 ± 0.0011		143 ± 16		13.1 ± 3.2		0.38 ± 0.03		59 ± 7		138 ± 13		2.32 ± 0.18		27 ± 2		18.1 ± 1.3		136 ± 6
P. Chèvres (4)	**	0.0060 ± 0.0019		63 ± 6		17.3 ± 2.7		0.34 ± 0.02		45 ± 2		82 ± 4		2.07 ± 0.12		29 ± 2		12.0 ± 0.4		91 ± 5
Riou (5)	**	0.0037 ± 0.0016		27 ± 4		1.6 ± 0.1		0.18 ± 0.02		42 ± 3		57 ± 4		2.30 ± 0.15		34 ± 2		10.9 ± 0.7		94 ± 6
Bénat (6)	*	0.0080 ± 0.0022		90 ± 18		1.8 ± 0.2		0.22 ± 0.02		63 ± 4		95 ± 9		2.89 ± 0.31		35 ± 3		12.5 ± 1.5		90 ± 7
Giens (7)	*	0.0088 ± 0.0018		144 ± 19		1.8 ± 0.4		0.25 ± 0.02		69 ± 4		134 ± 11		3.42 ± 0.31		35 ± 1		12.8 ± 1.4		122 ± 5
Cap Roux (8)	*	0.0095 ± 0.0015		120 ± 15		8.7 ± 1.7		0.26 ± 0.01		74 ± 7		78 ± 5		3.23 ± 0.27		35 ± 3		9.9 ± 0.7		85 ± 5
St Raphaël (9)	**	0.0066 ± 0.0010		41 ± 8		3.4 ± 0.8		0.21 ± 0.02		93 ± 14		56 ± 6		4.49 ± 0.72		48 ± 4		12.6 ± 1.6		123 ± 13
Antibes (10)	*	0.0072 ± 0.0015		95 ± 13		22.9 ± 6.5		0.27 ± 0.03		52 ± 5		91 ± 6		2.40 ± 0.17		29 ± 2		14.2 ± 1.2		65 ± 5
Villefranche (11)	*	0.0076 ± 0.0021		60 ± 6		12.3 ± 4.1		0.31 ± 0.05		57 ± 12		85 ± 3		1.97 ± 0.21		20 ± 2		22.9 ± 1.4		83 ± 5
Corsica																				
Calvi (I)	**	0.0060 ± 0.0013		20 ± 3		8.9 ± 1.3		0.16 ± 0.02		48 ± 4		41 ± 2		1.90 ± 0.09		29 ± 2		6.8 ± 0.7		69 ± 6
Aregno (II)	**	0.0050 ± 0.0018		66 ± 11		1.6 ± 0.1		0.22 ± 0.05		56 ± 2		69 ± 15		3.16 ± 0.11		32 ± 1		15.0 ± 0.9		109 ± 7
Saint Florent (III)	**	0.0042 ± 0.0015		102 ± 18		2.8 ± 0.4		0.98 ± 0.12		45 ± 4		135 ± 16		1.97 ± 0.20		24 ± 1		9.2 ± 0.9		73 ± 8
Taglio Isolaccio (IV)	*	0.0090 ± 0.0015		120 ± 13		18.6 ± 5.6		0.51 ± 0.04		89 ± 9		140 ± 9		2.32 ± 0.15		28 ± 1		10.7 ± 0.7		88 ± 9
Bravone (V)	*	0.0090 ± 0.0009		147 ± 32		2.3 ± 0.3		0.60 ± 0.08		77 ± 8		179 ± 29		3.62 ± 0.25		29 ± 2		22.6 ± 1.8		1282 ± 241
Ajaccio Sud (VI)	*	0.0077 ± 0.0012		112 ± 24		3.5 ± 0.9		0.21 ± 0.03		56 ± 2		80 ± 9		2.65 ± 0.09		34 ± 1		8.4 ± 0.3		89 ± 6
Ajaccio Nord (VII)		0.0113 ± 0.0014		151 ± 29		6.8 ± 2.8		0.24 ± 0.02		55 ± 2		143 ± 7		1.56 ± 0.06		22 ± 1		7.5 ± 0.4		72 ± 7

Table 1 (Continued)

	As	Se	Mo	Ag	Cd	Sn	Sb	Pb	Bi
A: CRM									
CRM values									
BCR 60	8.00	0.70	2.00		2.20 ± 0.10				
BCR 62	0.20	0.10	0.20		0.10 ± 0.02				
GBW 07603	1.25 ± 0.15	0.12 ± 0.02	0.28 ± 0.05	0.05 ± 0.01	0.38	0.270	0.095 ± 0.014	47.0 ± 3.0	0.023 ± 0.005
V463			0.83 ± 0.08		1.66 ± 0.32				
Our values									
BCR 60 (n = 7–22)	6.02 ± 0.27	0.66 ± 0.25	0.85 ± 0.04		2.00 ± 0.07				
BCR 62 (n = 15–19)	0.20 ± 0.01	0.28 ± 0.11	0.21 ± 0.02		0.09 ± 0.01				
GBW 07603 (n = 10–28)	1.21 ± 0.10	0.14 ± 0.05	0.32 ± 0.02	0.05 ± 0.01	0.76 ± 0.06	0.265 ± 0.056	0.081 ± 0.005	47.3 ± 1.5	0.025 ± 0.010
V463 (n = 15–28)			0.48 ± 0.05		1.47 ± 0.13				
	As	Se	Mo	Ag	Cd	Sn	Sb	Pb	Bi
B: Plant tissues									
3IL (trends; n = 72–74)	b 1.73 ± 0.64	*a 0.25 ± 0.05	a 2.25 ± 1.15	b 0.93 ± 0.20	a 2.60 ± 0.53	ND	b 0.196 ± 0.029	b 1.96 ± 0.93	a 0.0105 ± 0.0061
OIL (trends; n = 73)	ab 1.62 ± 0.58	ab 0.26 ± 0.04	ab 2.04 ± 0.74	abc 1.03 ± 0.21	ab 2.46 ± 0.43	**a 0.022 ± 0.021	b 0.178 ± 0.025	b 1.73 ± 0.87	ab 0.0088 ± 0.0054
BAL (trends; n = 71–73)	a 2.12 ± 0.80	a 0.26 ± 0.05	a 2.54 ± 1.27	c 0.68 ± 0.17	a 2.53 ± 0.60	*a 0.041 ± 0.025	a 0.243 ± 0.025	a 3.02 ± 1.44	a 0.0152 ± 0.0100
SAL (trends; n = 54–55)	b 1.26 ± 0.43	b 0.12 ± 0.05	a 0.82 ± 0.23	a 1.21 ± 0.27	b 1.18 ± 0.24	ND	*c 0.014 ± 0.008	c 0.61 ± 0.22	**b 0.0035 ± 0.0021
Shoot (trends; n = 217)	1.81 ± 0.64	** 0.24 ± 0.04	2.20 ± 0.95	0.90 ± 0.16	2.40 ± 0.45	** 0.024 ± 0.020	0.191 ± 0.020	2.14 ± 0.96	0.0109 ± 0.0064
	As	Se	Mo	Ag	Cd	Sn (BAL)	Sb	Pb	Bi
C: Sites									
PACA									
Ensues (1)	3.51 ± 0.41	* 0.30 ± 0.02	1.64 ± 0.22	0.91 ± 0.06	2.13 ± 0.08	* 0.041 ± 0.012	0.192 ± 0.009	2.58 ± 0.16	0.0169 ± 0.0011
La Vesse (2)	2.15 ± 0.22	* 0.27 ± 0.02	1.19 ± 0.08	1.63 ± 0.11	2.40 ± 0.11	0.105 ± 0.017	0.159 ± 0.007	4.09 ± 0.44	0.0269 ± 0.0034
Corbière (3)	2.54 ± 0.15	** 0.24 ± 0.02	1.62 ± 0.19	0.94 ± 0.09	1.78 ± 0.07	0.115 ± 0.028	0.222 ± 0.020	4.22 ± 0.49	0.0227 ± 0.0021
P. Chèvres (4)	9.44 ± 0.92	* 0.29 ± 0.03	2.27 ± 0.91	0.97 ± 0.04	2.18 ± 0.10	0.055 ± 0.013	0.184 ± 0.008	3.26 ± 0.33	0.0493 ± 0.0037
Riou (5)	1.73 ± 0.10	** 0.22 ± 0.02	1.21 ± 0.11	1.02 ± 0.07	2.95 ± 0.12	* 0.017 ± 0.007	0.169 ± 0.011	1.33 ± 0.13	0.0135 ± 0.0015
Bénat (6)	1.28 ± 0.11	** 0.22 ± 0.02	1.68 ± 0.23	1.03 ± 0.12	2.86 ± 0.16	* 0.024 ± 0.003	0.189 ± 0.025	1.30 ± 0.11	0.0051 ± 0.0005
Giens (7)	0.98 ± 0.05	** 0.22 ± 0.01	1.28 ± 0.11	0.97 ± 0.05	2.99 ± 0.13	* 0.026 ± 0.004	0.182 ± 0.014	1.62 ± 0.13	0.0051 ± 0.0005
Cap Roux (8)	1.71 ± 0.08	** 0.19 ± 0.02	1.75 ± 0.13	0.80 ± 0.07	2.87 ± 0.22	* 0.038 ± 0.012	0.218 ± 0.013	1.34 ± 0.17	0.0068 ± 0.0003
St Raphaël (9)	1.17 ± 0.09	* 0.29 ± 0.04	1.64 ± 0.24	1.05 ± 0.09	4.21 ± 0.41	* 0.020 ± 0.003	0.185 ± 0.032	1.11 ± 0.13	0.0053 ± 0.0005
Antibes (10)	2.80 ± 0.32	* 0.27 ± 0.02	3.29 ± 0.96	0.83 ± 0.07	2.12 ± 0.08	* 0.027 ± 0.004	0.190 ± 0.017	1.22 ± 0.09	0.0087 ± 0.0012
Villefranche (11)	1.79 ± 0.11	** 0.23 ± 0.03	3.89 ± 1.35	0.71 ± 0.05	1.08 ± 0.06	0.098 ± 0.008	0.243 ± 0.023	3.82 ± 0.67	0.0240 ± 0.0024
Corsica									
Calvi (I)	2.87 ± 0.37	* 0.31 ± 0.02	5.23 ± 1.08	0.55 ± 0.04	2.45 ± 0.10	* 0.019 ± 0.002	0.175 ± 0.006	1.52 ± 0.23	0.0056 ± 0.0003
Aregno (II)	0.97 ± 0.02	* 0.29 ± 0.03	27.03 ± 13.88	1.01 ± 0.08	3.74 ± 0.11	* 0.023 ± 0.027	0.182 ± 0.007	1.10 ± 0.07	* 0.0036 ± 0.0004
Saint Florent (III)	0.89 ± 0.06	** 0.20 ± 0.03	1.44 ± 0.13	0.56 ± 0.04	1.65 ± 0.07	* 0.026 ± 0.010	0.179 ± 0.047	1.98 ± 0.40	0.0063 ± 0.0009
Taglio Isolaccio (IV)	1.20 ± 0.17	** 0.20 ± 0.05	3.17 ± 1.09	0.75 ± 0.05	2.17 ± 0.10	* 0.025 ± 0.010	0.173 ± 0.012	1.17 ± 0.10	0.0066 ± 0.0008
Bravone (V)	1.19 ± 0.18	** 0.18 ± 0.02	1.58 ± 0.19	1.14 ± 0.10	2.49 ± 0.12	0.059 ± 0.037	0.699 ± 0.130	2.55 ± 0.44	0.0055 ± 0.0003
Ajaccio Sud (VI)	2.21 ± 0.16	* 0.28 ± 0.03	3.37 ± 0.30	1.13 ± 0.12	2.45 ± 0.14	0.072 ± 0.054	0.201 ± 0.021	2.32 ± 0.49	0.0105 ± 0.0013
Ajaccio Nord (VII)	1.70 ± 0.09	** 0.20 ± 0.02	2.38 ± 0.21	0.52 ± 0.02	1.56 ± 0.08	0.080 ± 0.029	0.188 ± 0.015	4.85 ± 0.92	0.0134 ± 0.0012

Fig. 1. Map showing the locations of the study sites along the Provence-Alpes-Côte d'Azur (PACA) and Corsican coasts.

for Cd and Pb; Lafabrie et al. (2008) for Cr, Co, Ni, Cd and Pb; Conti et al. (2010) for Cr, Cu, Zn, Cd and Pb.

Assimilation of TE among rooted aquatic plants occurs through two pathways: uptake by leaves from the water column or by roots from interstitial water. A preferential assimilation from the water column to photosynthetic tissues can be assumed for TE which show higher levels in these tissues. This is particularly true for V, Mn, Co, Ni, Zn, Mo, Cd, Sb, Pb and Bi, which was also suggested by Lafabrie et al. (2008) for Co, Ni, Cd, Hg and Pb.

At least two hypotheses can be used to explain the differences between photosynthetic tissues (upper values in BAL): (i) longer exposure to TE loaded in the ambient habitat, as suggested by

Warnau et al. (1996) for adult leaves compared to intermediate leaves, and by Campanella et al. (2001) for the tip of the leaf compared to its younger basal part; (ii) dilution effect due to the higher growth rate of intermediate leaves. These hypotheses can only play a major role for TE characterized by low kinetics of accumulation and little regulation such as Mn, Co, Ni, As, Mo, Sb, Pb, Bi and V.

On the other hand, the different behaviour of TE preferentially accumulated in SAL suggests different uptake and distribution routes. For the particular case of Cu, the systematic but quite limited upper level in SAL (as opposed to BAL) could be explained by an increase in metabolic activity during growth, when Cu (an essential micronutrient) is needed, as mentioned by Conti et al. (2010).

Fig. 2. *Posidonia oceanica* compartmentalization of V, Zn, Cr and Cu (a–d) at 4 of the 18 sites; levels are expressed as mean $\pm$ standard deviation in $\mu\text{g g DW}^{-1}$; letters represent significant differences between tissues ($p < 0.05$); third intermediate leaves (3IL), other intermediate leaves (OIL), blades of adult leaves (BAL) and sheaths of adult leaves (SAL); numbers in parentheses represent number of replicates.

Physiological metrics vary with the tissue age and are influenced by the presence of epiphytes. However, this work supports the hypothesis of Romero et al. (2007b) concerning 3IL, except for sites widely contaminated by TEs which are characterized by low kinetics of accumulation from the water column, such as V. For most of the TEs analysed, future analyses of TE levels could be done using this single 3IL sample. This will simplify the laboratory pretreatment process and also permit a non-destructive sampling strategy: only *P. oceanica* leaves will have to be cut *in situ* close to their basal part, which avoids uprooting the shoots and permits the subsequent regrowing of leaves (Gobert, pers. comm.).

3.2. Spatial (temporal) variation of trace element levels

Some TEs exhibit spatial variation of their levels in *P. oceanica* (higher than a factor 10 for Mo, Zn, V, Bi, Sn and As), while others show moderate (by a factor of between 4 and 10 for Al, Cr, Fe, Pb and Sb) and several exhibit small (lower than a factor 4 for Cd, Cu, Ag, Be, Co, Ni, Mn and Se) spatial variation (Table 1C and Fig. 3).

3.2.1. Be–Se

In all sites and tissues, Be and Se signals could be detected and measured, but the differences between sites were not really quantifiable as levels were close to L_D (0.007 and $0.27 \mu\text{g g}_{\text{DW}}^{-1}$, respectively). Barwick and Maher (2003) determined upper Se levels in one seagrass (*Zostera capricornii*; $0.38 \pm 0.08 \mu\text{g g}_{\text{DW}}^{-1}$) and in one green macroalga (*Enteromorpha* sp.; $0.34 \pm 0.09 \mu\text{g g}_{\text{DW}}^{-1}$) in Lake Macquarie (New South Wales, Australia), an estuary considered to be contaminated, whereas Baldwin et al. (1996) determined lower Se levels in *Posidonia australis* ($0.064 \pm 0.009 \mu\text{g g}_{\text{DW}}^{-1}$) in Jervis Bay (Australia), an estuary considered to be unpolluted. Levels recorded in the present study, which do not differ much between different sites, appear to reflect the background level of the northwestern Mediterranean Sea.

3.2.2. Sn (Fig. 3a)–Bi (Fig. 3b)

Sn and Bi had levels close to L_Q (0.07 and $0.005 \mu\text{g g}_{\text{DW}}^{-1}$, respectively); contrary to levels of Be and Se, a significant spatial variation was perceptible and quantifiable. Moreover, elevated levels were recorded for both elements at the same sites: Marseilles Bay (Ensuès, La Vesse, Corbière and Plateau des Chèvres), Villefranche and Ajaccio. Since they are principally used in specialized industry (Bi is also used in medicine and Sn was largely used in antifouling paints as tributyltin or TBT), it is not surprising to record elevated values in industrialized areas and harbours. Little data are available concerning Bi levels in aquatic macrophytes. Bertine et al. (1996) determined a similar range of levels in some brown and red algae (from 0.0046 to $0.0480 \mu\text{g}_{\text{Bi}} \text{g}_{\text{DW}}^{-1}$). Sn and its compounds (mainly TBT) are largely studied in molluscs, since TBT is an endocrine disruptor in gastropods (e.g. *Nucella lapillus*) and is particularly persistent in sediment (Santos et al., 2002). However, macrophytes, including the seagrass *Ruppia maritima*, are also affected by TBT stored in sediment (Jensen et al., 2004) in realistic environmental levels ($10 \mu\text{g}_{\text{TBT-Sn}} \text{kg}_{\text{DW}}^{-1}$).

3.2.3. V (Fig. 3c)

Since V is a tracer of oil spill (hydrocarbon) pollutants (Amiard et al., 2003; Alfonso et al., 2008), the presence of four oil refineries in the 13th French district (Bouches-du-Rhône), an old oil-exporting harbour at Antibes and the petroleum depot at Lucciana (Taglio Isolaccio) can explain the high V levels in Marseilles Bay, Antibes and Taglio Isolaccio. V levels varied from $1.6 \pm 0.1 \mu\text{g g}_{\text{DW}}^{-1}$ at Riou and Aregno, to $22.9 \pm 6.5 \mu\text{g g}_{\text{DW}}^{-1}$ at Antibes. Alfonso et al. (2008) found higher V levels in below-ground tissues (4.49 – $15.14 \mu\text{g g}_{\text{DW}}^{-1}$) than in above-ground tissues (1.09 – $2.20 \mu\text{g g}_{\text{DW}}^{-1}$) of *Thalassia testudinum*. They attributed the

highest levels in root-rhizomes to petroleum refining and transportation activities. Furthermore, the highest levels determined by Amiard et al. (2003) in three mollusc species: *Mytilus edulis* ($0.98 \mu\text{g g}_{\text{DW}}^{-1}$), *Nucella lapillus* ($0.57 \mu\text{g g}_{\text{DW}}^{-1}$) and *Littorina littorea* ($1.42 \mu\text{g g}_{\text{DW}}^{-1}$) along the south coast of Brittany (France), after the sinking of the tanker *Erika*, are in the lower range of the levels determined in this study. These observations confirm the use of *P. oceanica* as a good biological indicator of hydrocarbon pollution.

3.2.4. Mn–Mo (Fig. 3d)

The spatial variation of Mn levels was small. Furthermore, our levels (42 – $93 \mu\text{g g}_{\text{DW}}^{-1}$), and particularly our SAL levels (8 – $28 \mu\text{g g}_{\text{DW}}^{-1}$), were in the lower range of the values determined by Ancora et al. (2004) in *P. oceanica* scales in the Gulf of Naples (5 – $200 \mu\text{g g}_{\text{DW}}^{-1}$). Mo is an essential micronutrient for citrus culture (Srivastava and Shyam, 2007). Aregno, known for its culture of oranges and almonds, is located in the small catchment basin of Nonza, an agricultural valley that opens onto the sea. The particularly high Mo levels measured at Aregno are probably due to this specific agricultural activity. However, the levels at the 17 other sites are lower than those determined by Augier et al. (1991) in *P. oceanica* leaves ($5.2 \pm 0.6 \mu\text{g g}_{\text{DW}}^{-1}$) at the uncontaminated site of La Palu (Port Cros Island, France). So, measured levels of these two TEs (Mn: $60 \pm 10 \mu\text{g g}_{\text{DW}}^{-1}$; Mo: $2.20 \pm 0.95 \mu\text{g g}_{\text{DW}}^{-1}$) should reflect the background levels of the northwestern Mediterranean Sea.

3.2.5. Ag (Fig. 3e)

Chiffolleau et al. (2005) used wide mussels (*Mytilus edulis* and *Mytilus galloprovincialis*) and determined contamination by Ag along the French Mediterranean coast as homogeneous and limited compared to the Atlantic coast. However, the lowest values recorded from this study ($\sim 0.5 \mu\text{g g}_{\text{DW}}^{-1}$) were found in Corsica, and corroborate the low values measured by Lopez y Royo et al. (2009) in the northwestern Mediterranean Sea. Hence, these low levels should reflect the Ag background level of this area. Higher values in Corsica ($\sim 1 \mu\text{g g}_{\text{DW}}^{-1}$) correspond to the lower ones of the PACA region. This could stem from diffuse urban or industrialized contamination, with the exception of La Vesse ($1.63 \pm 0.11 \mu\text{g g}_{\text{DW}}^{-1}$) which seems to be more locally contaminated, as observed by Lopez y Royo et al. (2009) at Ile Rousse ($1.55 \pm 0.20 \mu\text{g g}_{\text{DW}}^{-1}$).

3.2.6. Sb (Fig. 3f)–As (Fig. 3g)–Zn (Fig. 3h)

With the exception of Bravone (Sb and Zn) and Plateau des Chèvres (As), these TEs have relatively small spatial variation. Levels of Zn and As found in this study correspond to unpolluted sites when compared to the literature (Tranchina et al., 2004; Fourqurean et al., 2007). The high Sb levels detected only at Bravone could be attributed to the As/Sb deposit at Matra. This mine, which closed in 1946, is crossed by the Presa River, a tributary of the Bravone River which flows into the open sea close to the city of the same name (Bravone). However, if the high Sb levels are associated with high Zn levels (which could also be attributed to the Matra deposit), it is not the case with As, as shown in mussels by Andral et al. (2004). On the other hand, the high As levels detected only at Plateau des Chèvres corroborate the observation made by Andral et al. (2004), and could be attributed to the industrial history of the south of Marseilles, chronically contaminated by As and Pb, as suggested by Lassalle (2007).

3.2.7. Al (Fig. 3i)–Fe

Al and Fe have similar profiles; this is consistent with the observations of Barabasz et al. (2002): one effect of Al on plants is the stimulation of Fe absorption by the root system. Our range of levels for Fe (41 – $179 \mu\text{g g}_{\text{DW}}^{-1}$) corroborates the low range of values

Fig. 3. Spatial variation of Sn, Bi, V, Mo, Ag, Sb, As, Zn, Al, Cr, Co and Pb (a–l) levels in *Posidonia oceanica* above-ground tissues at the 18 sites: Ensues (1), La Vesse (2), Corbière (3), P. Chèvres (4), Riou (5), Bénat (6), Giens (7), Cap Roux (8), St Raphaël (9), Antibes (10), Villefranche (11), Calvi (I), Aregno (II), St Florent (III), Taglio Isolaccio (IV), Bravone (V), Ajaccio Sud (VI) and Ajaccio Nord (VII); x-axis labels indicate the sites along the coasts (1–11: PACA; I–VII: Corsica); levels are expressed as mean $\pm$ standard deviation in $\mu\text{g}_{\text{g}_{\text{DW}}}^{-1}$.

determined by Fourqurean et al. (2007) in the Balearic Islands (Spain), and by Warnau et al. (1995) and Pergent-Martini (1994) at Calvi and Marseilles. However, no extreme level was determined at the 18 selected sites, as measured by Warnau et al. (1995) at Lacco Ameno ($419 \pm 431 \mu\text{g g}_{\text{DW}}^{-1}$; Ischia Island, Italy). Hence, these observations allow us to hypothesize that the spatial distribution results from a natural heterogeneity rather than anthropogenic activities. Fe deficiencies ($<100 \mu\text{g}_{\text{Fe}} \text{g}_{\text{DW}}^{-1}$) have been found in seagrasses growing above carbonate sediment (Duarte et al., 1995), but the low Fe levels determined at Calvi ($48 \pm 4 \mu\text{g g}_{\text{DW}}^{-1}$) do not negatively affect *P. oceanica* growth. Indeed, *P. oceanica* shoot biomass and leaf chlorophyll levels were high at Calvi (Gobert, pers. comm.), and the state of the *P. oceanica* meadow was determined as “good” according to PREI (Gobert et al., 2009). Furthermore, the low levels of other micronutrients (Mn, Co, Ni, Cu and Zn) determined at Calvi seem also not to be deficient for *P. oceanica*.

3.2.8. Cr (Fig. 3j)–Co (Fig. 3k)–Ni–Cd

The high Cr levels determined at Saint Florent ($0.98 \pm 0.12 \mu\text{g g}_{\text{DW}}^{-1}$) corroborate similar high values determined west of Cap Corse ($1.07 \pm 0.07 \mu\text{g g}_{\text{DW}}^{-1}$) by Lafabrie et al. (2008) using *P. oceanica* leaves and by Andral et al. (2004) using the RINBIO biointegrator network based on mussel caging. These values have been linked to waste from the disused Canari asbestos mine, closed in 1965, located at the northwestern area of the Gulf of Saint Florent. However, contrary to Lafabrie et al. (2008) and Andral et al. (2004), the high Cr levels at Saint Florent were not associated with high levels of Co or Ni, which were presumed to be linked to waste from the disused Canari asbestos mine. Furthermore, the spatial distribution of Co and Ni appeared to be more similar to that of Cd than to that of Cr. However, Co, Ni and Cd had low spatial variation and the ranges of levels for these three TEs were quite narrow, which reflect similar contamination levels across sites. Moreover, a decrease in Cd levels is observed at Calvi, St Florent and Ajaccio, when compared to Lafabrie et al. (2008).

3.2.9. Cu

Cu has several uses, including use as conductor, a constituent of alloys, as a copolymer, in antifouling paint, in ship rustproof enamel, and as a fungicide, an algicide, fertilizer, etc. Hence, there may be multiple sources of contamination which are yet to be specified in the more contaminated sites of Bravone, Aregno, Villefranche, La Vesse and Corbière. However, levels determined in this study ($7.5\text{--}22.9 \mu\text{g g}_{\text{DW}}^{-1}$) were clearly lower than those determined by Conti et al. (2007) at Ustica Island ($31.9 \pm 15.8 \mu\text{g g}_{\text{DW}}^{-1}$; Sicily, Italy) where TE contamination was estimated at a medium-low level according to the literature. All sites sampled can thus be considered as having a low level of Cu contamination.

3.2.10. Pb (Fig. 3l)

Pb, not highly soluble in sea water, accumulates in sediments. Nevertheless, Mayes et al. (1977) suggested for another rooted aquatic plant (*Elodea canadensis*) that movement of Pb from contaminated sediment to leaves probably occurs through the water (released from the sediment by turbulence), and not through internal transport (acropetal translocation). Since its prohibited use as an anti-knock additive in gasoline (lead alkyls) and as the principal component of water pipes, contamination levels of Pb have been in decline, as determined by Ancora et al. (2004) between 1989 and 1999 in the Gulf of Naples. Moreover, Tranchina et al. (2005) determined that Pb levels measured in *P. oceanica* scales were statistically correlated to Pb emissions in the air and reflected the level of Pb pollution in the coastal marine environment. However, its significant environmental persistence in the sediment explains the

relatively higher values determined in the highest industrialized sites (Marseilles Bay, Villefranche and Ajaccio).

4. Conclusion

The general trends of compartmentalization in *P. oceanica* allow us to propose hypotheses concerning the uptake and distribution routes of these nineteen TEs. However, such hypotheses have yet to be confirmed either by means of analysis of different parts of the same leaf (whole leaf, leaf tip and leaf basal tissue), or by means of analysis of both above- (leaves) and below-ground (rhizomes, scales and roots) tissues. Alternatively, experimental contamination in controlled mesocosms would allow us to clarify the uptake and distribution routes of TEs and to quantify the kinetics of accumulation and excretion. Furthermore, this study supports the hypothesis that future analyses of most TEs in *P. oceanica* in the spring could be undertaken only on the single third intermediate leaf, except for sites widely contaminated by TEs, such as V, characterized by very low kinetics of accumulation from the water column. On the scale of the Mediterranean French coast, the natural levels of most of the twelve little-studied TEs measured in *P. oceanica* could be determined, and their spatial variation as well as their contamination sources could be explained. *P. oceanica* effectively concentrates Be, Al, V, Mn, Co, As, Se, Mo, Ag, Sn, Sb and Bi from its surrounding environment, and might be used *de facto* as a sentinel species for their coastal monitoring. Special attention should be given to these twelve potentially toxic TEs due to their local (Mo), diffuse (Ag) and/or chronic (As) observed contamination. On the other hand, the levels of the seven widely studied TEs (Cr, Fe, Ni, Cu, Zn, Cd and Pb) seem to decrease or stabilize over time, probably due to their reduced anthropogenic inflows. These observations taken together suggest that *P. oceanica* is a sensitive bioindicator for the monitoring of chemical contamination for the nineteen TEs studied.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.ecolind.2011.11.005.

References

- Alfonso, J.A., Azocar, J., LaBrecque, J.J., Garcia, B., Palacios, D., Benzo, Z., 2008. Trace metals in bivalves and seagrass collected from Venezuelan coastal sites. *Revista de biología tropical* 56, 215–222.
- Amiard, J.-C., Bacheley, H., Barillé, A.-L., Barillé, L., Geffard, A., Himery, N., 2003. Temporal changes in nickel and vanadium concentrations and in condition index and metallothionein levels in three species of molluscs following the “Erika” oil spill. *Aquatic Living Resources* 17, 281–288.
- Ancora, S., Bianchi, N., Butini, A., Buia, M.C., Gambi, M.C., Leonzio, C., 2004. *Posidonia oceanica* as a biomonitor of trace elements in the Gulf of Naples: temporal trends by lepidochronology. *Environmental Toxicology and Chemistry* 23, 1093–1099.
- Andral, B., Stanisiere, J.Y., Sauzade, D., Damier, E., Thebault, H., Galgani, F., Boissery, P., 2004. Monitoring chemical contamination levels in the Mediterranean based on the use of mussel caging. *Marine Pollution Bulletin* 49, 704–712.
- Augier, H., Ronneau, C., Roucoux, P., Lion, R., Charlent, O., 1991. Neutron-activation analysis of the elementary composition of the marine phanerogam *Posidonia oceanica* from a reference area in Port Cros National Park (French Mediterranean). *Marine Biology* 109, 345–353.

- Babula, P., Adam, V., Opatrilova, R., Zehnalek, J., Havel, L., Kizek, R., 2008. Uncommon heavy metals, metalloids and their plant toxicity: a review. *Environmental Chemistry Letters* 6, 189–213.
- Baldwin, S., Maher, W., Kleber, E., Krikowa, F., 1996. Selenium in marine organisms of seagrass habitats (*Posidonia australis*) of Jervis Bay, Australia. *Marine Pollution Bulletin* 32, 310–316.
- Barabasz, W., Albinska, D., Jaskowska, M., Lipiec, J., 2002. Ecotoxicology of aluminium. *Polish Journal of Environmental Studies* 11, 199–203.
- Barwick, M., Maher, W., 2003. Biotransference and biomagnification of selenium copper, cadmium, zinc, arsenic and lead in a temperate seagrass ecosystem from Lake Macquarie Estuary, NSW, Australia. *Marine Environmental Research* 56, 471–502.
- Bertine, K., Koide, M., Goldberg, E., 1996. Comparative marine chemistries of some trivalent metals – bismuth, rhodium and rare earth elements. *Marine Chemistry* 53, 89–100.
- Boudouresque, C.F., Bernard, G., Bonhomme, P., Charbonnel, E., Diviacco, G., Meinesz, A., Pergent, G., Pergent-Martini, C., Ruitton, S., Tunesi, L., 2006. Préservation et conservation des herbiers à *Posidonia oceanica*. Ramoge Pub, pp. 1–202.
- Boudouresque, C.F., Meinesz, A., 1982. Découverte de l'herbier de posidonie. In: Parc national de Port-Cros, Parc naturel régional de la Corse and GIS Posidonie, pp. 1–79.
- Campanella, L., Conti, M.E., Cubadda, F., Sucapane, C., 2001. Trace metals in seagrass, algae and molluscs from an uncontaminated area in the Mediterranean. *Environmental Pollution* 111, 117–126.
- Chiffolleau, J.F., Auger, D., Roux, N., Rozuel, E., Santini, A., 2005. Distribution of silver in mussels and oysters along the French coasts: data from the national monitoring program. *Marine Pollution Bulletin* 50, 1719–1723.
- Conti, M., Bocca, B., Iacobucci, M., Finio, M., Mecozzi, M., Pino, A., 2010. Baseline trace metals in seagrass, algae, and mollusks in a Southern Tyrrhenian Ecosystem (Linosa Island, Sicily). *Archives of Environmental Contamination and Toxicology* 58, 79–95.
- Conti, M., Iacobucci, M., Cecchetti, G., 2007. A biomonitoring study: trace metals in seagrass, algae and molluscs in a marine reference ecosystem (Southern Tyrrhenian Sea). *International Journal of Environment and Pollution* 29, 308–332.
- Currie, L., 1999. Nomenclature in evaluation of analytical methods including detection and quantification capabilities (IUPAC Recommendations 1995). *Analytica Chimica Acta* 391, 105–126.
- Duarte, C.M., Merino, M., Gallegos, M., 1995. Evidence of iron deficiency in seagrasses growing above carbonate sediments. *Limnology and Oceanography* 40, 1153–1158.
- Duffus, J.H., 2002. “Heavy metals” – a meaningless term? (IUPAC technical report). *Pure and Applied Chemistry* 74, 793–807.
- EC, 2000. Directive 2000/60/EC of the European Parliament and the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. *Official Journal of the European Communities*, OJ L 327, 22.12.2000, pp. 1–73.
- Filella, M., Belzile, N., Chen, Y.W., 2002. Antimony in the environment: a review focused on natural waters – I: occurrence. *Earth-Science Reviews* 57, 125–176.
- Fourqurean, J., Marba, N., Duarte, C., Diaz-Almela, E., Ruiz-Halpern, S., 2007. Spatial and temporal variation in the elemental and stable isotopic content of the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* from the Illes Balears, Spain. *Marine Biology* 151, 219–232.
- Giraud, G., 1979. Sur une méthode de mesure et de comptage des structures foliaires de *Posidonia oceanica* (Linnaeus) Delile. *Bulletin du Muséum d'histoire naturelle de Marseille* 39, 33–39.
- Gobert, S., Sartoretto, S., Rico-Raimondino, V., Andral, B., Chery, A., Lejeune, P., Boisery, P., 2009. Assessment of the ecological status of Mediterranean French coastal waters as required by the Water Framework Directive using the *Posidonia oceanica* Rapid Easy Index: PREI. *Marine Pollution Bulletin* 58, 1727–1733.
- Grinzaid, E.L., Zil'bershtein, K.I., Nadezhina, L.S., Yufa, B.Y., 1977. Terms and methods of estimating detection limits in various analytical methods. *Journal of Analytical Chemistry USSR* 32, 1678–1684.
- Ikem, A., Egiebor, N.O., 2005. Assessment of trace elements in canned fishes (mackerel, tuna, salmon, sardines and herrings) marketed in Georgia and Alabama (United States of America). *Journal of Food Composition and Analysis* 18, 771–787.
- IUPAC, Inczédy, J., Lengyel, T., Ure, A.M., Gelencsér, A., Hulanicki, A., 1998. Compendium of Analytical Nomenclature, 3rd ed. Blackwell, Oxford.
- Jensen, H., Holmer, M., Dahllof, I., 2004. Effects of tributyltin (TBT) on the seagrass *Ruppia maritima*. *Marine Pollution Bulletin* 49, 564–573.
- Karlsson, S., Duker, A., Grahn, E., 2007. Sediment chronologies of As, Bi, and Ga in Sweden – impact of industrialisation. *Journal of Environmental Science and Health. Part A, Toxic/Hazardous Substances & Environmental Engineering* 42, 155–164.
- Kljakovic-Gaspic, Z., Antolic, B., Zvonaric, T., Baric, A., 2004. Distribution of cadmium and lead in *Posidonia oceanica* (L.) Delile from the middle Adriatic sea. *Fresenius Environmental Bulletin* 13, 1210–1215.
- Lafabrie, C., Pergent-Martini, C., Pergent, G., 2008. Metal contamination of *Posidonia oceanica* meadows along the Corsican coastline (Mediterranean). *Environmental Pollution* 151, 262–268.
- Lassalle, J.L., 2007. Présence de plomb et d'arsenic sur le littoral sud de Marseille: une étude de santé. Institut de Veille Sanitaire, Saint-Maurice, pp. 1–44.
- Lopez y Royo, C., Casazza, G., Pergent-Martini, C., Pergent, G., Royo, L., 2010. A biotic index using the seagrass *Posidonia oceanica* (BiPo), to evaluate ecological status of coastal waters. *Ecological Indicators* 10, 380–389.
- Lopez Royo, C., Silvestri, C., Salivas-Decaux, M., Pergent, G., Casazza, G., 2009. Application of an angiosperm-based classification system (BiPo) to Mediterranean coastal waters: Using spatial analysis and data on metal contamination of plants in identifying sources of pressure. *Hydrobiologia* 633, 169–179.
- Mayer, R., McIntosh, A., Anderson, V., 1977. Uptake of cadmium and lead by a rooted aquatic macrophyte (*Elodea canadensis*). *Ecology* 58, 1176–1180.
- Med-GIG, 2009. WFD Intercalibration technical report for coastal and transitional waters in the Mediterranean ecoregion. In: WFD Intercalibration Technical Report – Part 3: Coastal and Transitional Waters. Luxembourg, 10.
- Olesik, J., Jones, D., 2006. Strategies to develop methods using ion-molecule reactions in a quadrupole reaction cell to overcome spectral overlaps in inductively coupled plasma mass spectrometry. *Journal of Analytical Atomic Spectrometry* 21, 141–159.
- Pasqualini, V., Pergent-Martini, C., Clabaut, P., Pergent, G., 1998. Mapping of *Posidonia oceanica* using aerial photographs and side scan sonar: application off the Island of Corsica (France). *Estuarine, Coastal and Shelf Science* 47, 359–367.
- Pergent-Martini, C., 1994. Impact d'un rejet d'eaux usées urbaines sur l'herbier à *Posidonia oceanica*, avant et après la mise en service d'une station d'épuration. Docteur en Ecologie Marine, Faculté des Sciences, Université de Corse, 208.
- Pergent-Martini, C., Leoni, V., Pasqualini, V., Ardizzone, G.D., Balestri, E., Bedini, R., Belluscio, A., Belsher, T., Borg, J., Boudouresque, C.F., Boumaza, S., Bouqueneau, J.M., Buia, M.C., Calvo, S., Cebrian, J., Charbonnel, E., Cinelli, F., Cossu, A., Di Maida, G., Dural, B., Francour, P., Gobert, S., Lepoint, G., Meinesz, A., Molenaar, H., Mansour, H.M., Panayotidis, P., Peirano, A., Pergent, G., Piazzoli, L., Pirrotta, M., Relini, G., Romero, J., Sanchez-Lizaso, J.L., Semroud, R., Shembri, P., Shili, A., Tomasello, A., Velimirov, B., 2005. Descriptors of *Posidonia oceanica* meadows: use and application. *Ecological Indicators* 5, 213–230.
- Ravindra, K., Bencs, L., Van Grieken, R., 2004. Platinum group elements in the environment and their health risk. *The Science of the Total Environment* 318, 1–43.
- Romero, J., Martinez-Crego, B., Alcoverro, T., Perez, M., 2007a. Corrigendum to “A multivariate index based on the seagrass *Posidonia oceanica* (POMI) to assess ecological status of coastal waters under the water framework directive (WFD)”. *Marine Pollution Bulletin* 54, 631.
- Romero, J., Martinez-Crego, B., Alcoverro, T., Perez, M., 2007b. A multivariate index based on the seagrass *Posidonia oceanica* (POMI) to assess ecological status of coastal waters under the water framework directive (WFD). *Marine Pollution Bulletin* 55, 196–204.
- Santos, M., Hallers-Tjabbes, C.T., Santos, A., Vieira, N., 2002. Imposed in *Nucella lapillus*, a bioindicator for TBT contamination: re-survey along the Portuguese coast to monitor the effectiveness of EU regulation. *Journal of Sea Research* 48, 217–223.
- Schlacher-Hoenlinger, M.A., Schlacher, T.A., 1998. Accumulation, contamination, and seasonal variability of trace metals in the coastal zone – Patterns in a seagrass meadow from the Mediterranean. *Marine Biology* 131, 401–410.
- Srivastava, A., Shyam, S., 2007. Edaphology of molybdenum nutrition in citrus: a review. *Agricultural Reviews* 28, 93–106.
- Tranchina, L., Bellia, S., Brai, M., Hauser, S., Rizzo, S., Bartolotta, A., Basile, S., 2004. Chemistry, mineralogy and radioactivity in “*Posidonia oceanica*” meadows from North-Western Sicily. *Chemical Ecology* 20, 203–214.
- Tranchina, L., Micciche, S., Bartolotta, A., Brai, M., Mantegna, R.N., 2005. *Posidonia oceanica* as a historical monitor device of lead concentration in marine environment. *Environmental Science and Technology* 39, 3006–3012.
- Warnau, M., Fowler, S.W., Teyssie, J.L., 1996. Biokinetics of selected heavy metals and radionuclides in two marine macrophytes: the seagrass *Posidonia oceanica* and the alga *Caulerpa taxifolia*. *Marine Environmental Research* 41, 343–362.
- Warnau, M., Ledent, G., Temara, A., Bouqueneau, J., Jangoux, M., Dubois, P., 1995. Heavy metals in *Posidonia oceanica* and *Paracentrotus lividus* from seagrass beds of the north-western Mediterranean. *The Science of the Total Environment* 171, 95–99.
- Wieser, M.E., Schwieters, J.B., 2005. The development of multiple collector mass spectrometry for isotope ratio measurements. *International Journal of Mass Spectrometry* 242, 97–115.

Supplementary Table

Non exhaustive number of references concerning trace elements studied in *Posidonia oceanica* tissues; completed (black references) from Pergent-Martini et al. (2000) summary table (grey references).

Références	Cd	Hg	Pb	Cu	Zn	Cr	Fe	Ni	Cs	K	Na	As	Ca	Co	Mg	Se	Ag	Br	Mn	Ti	Al	Am
Augier et al. (1976, 1978a, 1978b, 1984, 1988); Maserti et Ferrara (1986); Cottiglia et al. (1988); Maserti et al. (1988, 1989, 1991); Ferrara (1989); Paterno et al. (1991); Bougerol et al. (1995) ; Pergent-Martini and Guerrini (1995); Pergent-Martini (1998); Pergent and Pergent-Martini (1999); Lafabrie et al. (2007a)		17																				
Ferrara et al. (1989)						1	1		1													
Augier et al. (1980)	1	1	1	1	1			1														
Vincente et Chabert (1981)	1		1	1				1														
Chabert et al. (1983)	1		1	1	1			1														
Catsiki et Florou (1984)	1			1		1		1	1													
Catsiki et al. (1987); Panayotidis (1988)	2	2				2		2	2													
Giaccone et al. (1988)		1		1		1																
Malea et Haritodinis (1989)	1		1	1	1																	
Panayotidis et al. (1990)	1			1		1																
Sanchiz et al. (1990)	1	1	1		1																	
Augier et al. (1991)					1	1	1		1	1	1					1		1				
Costantini et al. (1991)	1	1	1																			
Grauby et al. (1991)					1	1	1		1	1	1	1	1			1		1				
Taramelli et al. (1991); Carlotti et al. (1992)	2																					
Catsiki et Bei (1992)	1			1		1	1	1											1			
Catsiki et Panayotidis (1993)				1		1		1												1		
Ledent et al. (1993)	1		1	1	1	1	1													1		
Malea (1993)																					1	
Pergent-Martini et al. (1993)	1		1	1	1		1															
Schlacher-Hoenlinger and Schlacher (1998a, 1998b)	2		2	2	2																	
Augier et al. (1994)	1			1	1			1								1						
Catsiki et al. (1994)						1																
Malea et al. (1994)	1		1	1	1		1			1	1		1			1						
Duarte et al. (1995)							1															
Ledent et al. (1995)	1		1	1	1	1	1	1			1	1	1			1						
Romeo et al. (1995)	1		1	1	1		1	1											1		1	
Warnau et al. (1995)	1		1	1	1	1	1	1												1		
Warnau et al. (1996)	1					1			1									1				1
Sanchiz et al. (2000; 2001)	2	2	2		2																	
Campanella et al. (2001)	1		1	1	1	1																
Baroli et al. (2001)	1		1			1	1															
Ancora et al. (2004)	1	1	1	1	1		1															
Kljakovic-Gaspic et al. (2004)	1		1																			
Tranchina et al. (2004; 2005)	2		2	2	2																	
Maserti et al. (2005)	1	1																				
Gosselin et al. (2006)	1		1	1	1	1		1				1				1						
Fourqurean et al. (2007)						1						1										
Conti et al. (2007)	1		1	1	1	1																
Lafabrie et al. (2007b)		1	1	1		1		1						1								
Lafabrie et al. (2008a, 2008b)	2	2	2			2		2						2								
Lopez y Royo et al. (2009)	1	1	1	1				1									1					
Conti et al. (2010)	1	1	1	1	1	1																
Number of reference	38	31	29	27	25	22	14	13	7	4	4	3	3	2	3	3	2	2	2	2	1	1
	Cd	Hg	Pb	Cu	Zn	Cr	Fe	Ni	Cs	K	Na	As	Ca	Co	Mg	Se	Ag	Br	Mn	Ti	Al	Am

Supplementary references

- Ancora, S., N. Bianchi, A. Butini, M.C. Buia, M.C. Gambi and C. Leonzio, 2004. *Posidonia oceanica* as a biomonitor of trace elements in the Gulf of Naples: temporal trends by lepidochronology. *Environmental Toxicology and Chemistry* 23(5), 1093-1099.
- Augier, H., G. Gilles and G. Ramonda, 1976. Recherches sur la pollution mercurielle en rade d'Hyères et dans l'archipel des Stoechades (Méditerranée, France). 1 - Teneur en mercure des eaux, des sédiments et des phanérogames marines de milieu lagunaire de l'anse de Port-Cros (Parc National). *Travaux scientifiques Parc national de Port-Cros* 2, 23-28.
- Augier, H., G. Gilles and G. Ramonda, 1978a. Recherche sur la pollution mercurielle du milieu maritime dans la région de Marseille (Méditerranée, France): degré de contamination par le mercure de la Phanérogame marine *Posidonia oceanica* Delile à proximité du complexe portuaire et dans la zone de rejet du grand collecteur d'égout de la ville de Marseille. *Environmental Pollution* 17, 269-285.
- Augier, H., G. Gilles and G. Ramonda, 1978b. Recherche sur la pollution mercurielle dans le golfe de Fos (Méditerranée, France): degré de contamination par le mercure des Phanérogames marines *Posidonia oceanica* Delile, *Zostera noltii* Horneman et *Zostera marina* (L.). *Revue Internationale d'Océanographie Médicale* 51-52, 55-69.
- Augier, H., G. Gilles and G. Ramonda, 1980. Recherches sur la pollution mercurielle en rade d'Hyères et dans l'archipel des Stoechades (Méditerranée, France). 6 - Teneur en mercure de la flore et de la faune marines benthiques de la crique de la Licastre. *Travaux scientifiques Parc national de Port-Cros* 6, 133-145.
- Augier, H., G. Gilles and G. Ramonda, 1984. L'herbier de *Posidonia oceanica* et la pollution par le mercure sur le littoral des Bouches-du-Rhône et du Var (France), in: C. F. Boudouresque, A. Jeudy de Grissac and J. Olivier, *International Workshop Posidonia oceanica Beds*, GIS Posidonie publ., Marseille, 156.
- Augier, H., J. M. Harmand and G. Ramonda, 1994. Pleasure harbours are responsible for the metallic contamination of *Posidonia oceanica* meadows, in: E. Ozhan, *First International Conference on the Mediterranean Coastal Environment*, MEDCOAST 93, MEDCOAST Secretariat, Middle East Technical University publ., Ankara, 127-141.
- Augier, H., G. Ramonda, M. Santimone and C. Taglioni, 1988. Etude de la contamination mercurielle de la phanérogame marine *Posidonia oceanica* (L.) Delile dans la zone d'épandage des eaux usées de l'émissaire de Giens (Var, Méditerranée, France). *Rapport Commission Internationale pour l'Exploration Scientifique de la Méditerranée* 31(2), 156.
- Augier, H., C. Ronneau, P. Roucoux, R. Lion and O. Charlent, 1991. Neutron-activation analysis of the elementary composition of the marine phanerogam *Posidonia oceanica* from a reference area in Port Cros National Park (French Mediterranean). *Marine Biology* 109(2), 345-353.
- Baroli, M., A. Cristini, A. Cossu, G. de Falco, V. Gazale, C. Pergent-Martini and G. Pergent, 2001. Concentrations of trace metals (Cd, Cu, Fe and Pb) in *Posidonia oceanica* seagrass of Liscia Bay, Sardinia (Italy), in: Springer-Verlag, *Mediterranean Ecosystems: structures and processes*, Italy, Ch 13: 95-99.
- Bougerol, X., G. Pergent and J. Gilbert, 1995. Compared bioaccumulation of mercury between the marine phanerogam *Posidonia oceanica* and the herbivorous fish *Sarpa salpa*: preliminary results. *Rapport Commission Internationale pour l'Exploration Scientifique de la Méditerranée* 34, 135.
- Campanella, L., M. E. Conti, F. Cubadda and C. Sucapane, 2001. Trace metals in seagrass, algae and molluscs from an uncontaminated area in the Mediterranean. *Environmental Pollution* 111(1), 117-126.
- Carlotti, P., C. F. Boudouresque and D. Calmet, 1992. Mémorisation du cadmium et de radioéléments par les rhizomes et les écailles de *Posidonia oceanica* (Potamogetonaceae). *Travaux Scientifiques du Parc Naturel Régional et Réserves naturelles de Corse* 36, pp. 1-34.
- Catsiki, V. A. and H. Florou, 1984. Bioaccumulation des métaux Cr, Cd, Ni, et Cu dans le golfe de Gera, Ile de Lesbos, Mer Egée, Grèce (Note préliminaire). *Journées d'études sur les pollutions marines en Méditerranée*, Lucerne, C.I.E.S.M., 317-320.
- Catsiki, V. A., P. Panayotidis and E. Papathanassiou, 1987. Bioaccumulation of heavy metals by seagrasses in Greek coastal waters. *Posidonia Newsletter* 1(2), 21-30.
- Catsiki, V. A. and F. Bei, 1992. Determination of trace metals in benthic organisms from an unpolluted area: Cyclades Islands (Aegean Sea). *Fresenius Environmental Bulletin* 1, 60-65.
- Catsiki, V. and P. Panayotidis, 1993. Copper, chromium and nickel in tissues of the Mediterranean seagrasses *Posidonia oceanica* and *Cymodocea nodosa* (Potamogetonaceae) from Greek coastal areas. *Chemosphere* 26(5), 963-978.
- Catsiki, V., C. Katsilieri and V. Gialamas, 1994. Chromium distribution in benthic species from a gulf receiving tanney wastes (Gulf of Geras Lesbos Island, Greece). *The Science of the Total Environment* 145(1-2), 173-185.
- Chabert, D., N. Vicente and W. Huang, 1983. La pollution par les métaux lourds dans les rades du Parc national de Port-Cros. II. Contrôle pluriannuel. *Travaux scientifiques Parc national de Port-Cros* 9, 17-34.
- Conti, M., M. Iacobucci and G. Cecchetti, 2007. A biomonitoring study: trace metals in seagrass, algae and molluscs in a marine reference ecosystem (Southern Tyrrhenian Sea). *International Journal of Environment and Pollution* 29(1-3), 308-332.
- Conti, M., B. Bocca, M. Iacobucci, M. Finoia, M. Mecozzi and A. Pino, 2010. Baseline trace metals in seagrass, algae, and mollusks in a Southern Tyrrhenian Ecosystem (Linosa Island, Sicily). *Archives of Environmental Contamination and Toxicology* 58(1), 79-95.
- Costantini, S., R. Giordano, L. Ciaralli and E. Beccaloni, 1991. Mercury, cadmium and lead evaluation in *Posidonia oceanica* and *Codium tomentosum*. *Marine Pollution Bulletin* 22(7), 362-363.
- Cottiglia, M., C. Mascia, M. Porcu and L. Spanedda, 1988. Distribution and dynamics of mercury in organisms of *Posidonia oceanica* beds. *Annuaire Ist. Mus. Zool. Univ. Napoli* 26, 1-30.

- Duarte, C. M., M. Merino and M. Gallegos, 1995. Evidence of iron deficiency in seagrasses growing above carbonate sediments. *Limnology and Oceanography* 40(6), 1153-1158.
- Ferrara, R., B. E. Maserti and P. Paterno, 1989. Mercury distribution in marine sediment and its correlation with the *Posidonia oceanica* prairie in a coastal area affected by a chlor-alkali complex. *Toxicological and Environmental Chemistry* 22, 131-134.
- Fourqurean, J., N. Marba, C. Duarte, E. Diaz-Almela and S. Ruiz-Halpern, 2007. Spatial and temporal variation in the elemental and stable isotopic content of the seagrasses *Posidonia oceanica* and *Cymodocea nodosa* from the Illes Balears, Spain. *Marine Biology* 151(1), 219-232.
- Giaccone, G., A. Cossu, R. Delorenzo, D. Drago and P. N. Muscetta, 1988. Studio di impatto ambientale nell'area portuale antistante lo stabilimento industriale EniChem di Porto Torres. *Boll. Soc. Sarda Sci. Nat.* 26, 43-67.
- Gosselin, M., J.-M. Bouqueneau, F. Lefebvre, G. Lepoint, G. Pergent, C. Pergent-Martini and S. Gobert, 2006. Trace metal concentrations in *Posidonia oceanica* of North Corsica (northwestern Mediterranean Sea): use as a biological monitor? *BMC Ecology* 6(12), 1-19.
- Grauby, H., H. Augier, R. Lion and O. Charlent, 1991. Neutron activation analysis of elemental composition in marine phanerogam, *Posidonia oceanica* (L.) Delile: a biological indicator of pollution. *Environmental and Experimental Botany* 31(3), 255-263.
- Kljakovic-Gaspic, Z., B. Antolic, T. Zvonaric and A. Baric, 2004. Distribution of cadmium and lead in *Posidonia oceanica* (L.) Delile from the middle Adriatic Sea. *Fresenius Environmental Bulletin* 13(11B), 1210-1215.
- Lafabrie, C., G. Pergent, C. Pergent-Martini and A. Capiomont, 2007a. *Posidonia oceanica*: a tracer of past mercury contamination. *Environmental Pollution* 148(2), 688-692.
- Lafabrie, C., G. Pergent, R. Kantin, C. Pergent-Martini and J.L. Gonzalez, 2007b. Trace metals assessment in water, sediment, mussel and seagrass species - Validation of the use of *Posidonia oceanica* as a metal biomonitor. *Chemosphere* 68(11), 2033-2039.
- Lafabrie, C., C. Pergent-Martini and G. Pergent, 2008a. Metal contamination of *Posidonia oceanica* meadows along the Corsican coastline (Mediterranean). *Environmental Pollution* 151, 262-268.
- Lafabrie, C., C. Pergent-Martini and G. Pergent, 2008b. First results on the study of metal contamination along the Corsican coastline using *Posidonia oceanica*. *Marine Pollution Bulletin* 57(1-5), 155-159.
- Ledent, G., M. Warnau, A. Temara, M. Jangoux and P. Dubois 1993. Contamination par les métaux lourds et dynamiques de l'accumulation du cadmium chez la phanérogame marine *Posidonia oceanica*, in: C. F. Boudouresque, M. Avon and C. Pergent-Martini, *Qualité du milieu marin - Indicateurs biologiques et physico chimiques*, GIS Posidonie publ. Marseille, 249-259.
- Ledent, G., M. A. Mateo, M. Warnau, A. Temara, J. Romero and P. Dubois, 1995. Element losses following distilled water rinsing of leaves of the seagrass *Posidonia oceanica* (L.) Delile. *Aquatic Botany* 5(3), 229-235.
- Lopez y Royo, C., C. Silvestri, M. Salivas-Decaux, G. Pergent and G. Casazza, 2009. Application of an angiosperm-based classification system (BiPo) to Mediterranean coastal waters: using spatial analysis and data on metal contamination of plants in identifying sources of pressure. *Hydrobiologia* 633(1), 169-179.
- Malea, P. and S. Haritonidis, 1989. Uptake of Cu, Cd, Zn and Pb in *Posidonia oceanica* (Linnaeus) from Antikyra Gulf, Greece: preliminary note. *Marine Environmental Research* 28, 495-498.
- Malea, P., 1993. Bioaccumulation of aluminium in the seagrasses *Cymodocea nodosa* (Ucria) Aschers and *Posidonia oceanica* (L.) Delile and in macroalgae of the gulf of Antikyra (Greece). *Botanica Marina* 36(5), 423-431.
- Malea, P., S. Haritonidis and T. Kevrekidis, 1994. Seasonal and local variation of metal concentrations in the seagrass *Posidonia oceanica* (L.) Delile in the Antikyra Gulf, Greece. *The Science of the Total Environment* 153(3), 225-235.
- Maserti, B. E. and R. Ferrara, 1986. Observations on mercury uptake in *Posidonia oceanica* (L.) Delile. *Rapport de la Communauté Internationale de la Mer Méditerranée* 30(2), 24.
- Maserti, B. E., R. Ferrara and P. Paterno, 1988. *Posidonia* as an indicator of mercury contamination. *Marine Pollution Bulletin* 19(8), 381-382.
- Maserti, B. E., R. Ferrara and P. Paterno, 1989. Contributo della comunità epifita alla mobilitazione del mercurio nelle praterie di *Posidonia oceanica* (L.) Delile. *Oebalia* 15(1), 183-187.
- Maserti, B. E., R. Ferrara and M. Morelli, 1991. *Posidonia oceanica*: uptake and mobilization of mercury in the Mediterranean basin. *FAO/UNEP/IAEA consultation meeting on the accumulation and transformation of chemical contaminants by biotic and abiotic processes in the marine environment*. MAP Technical Reports 59, 1-392.
- Maserti, B. E., V. Ferrillo, O. Avdis, U. Nesti, A. Di Garbo, A. Catsiki and P. L. Maestrini, 2005. Relationship of non-protein thiol pools and accumulated Cd or Hg in the marine macrophyte *Posidonia oceanica* (L.) Delile. *Aquatic Toxicology* 75(3), 288-292.
- Panayotidis, P., 1988. Etude de l'impact de la pollution sur les herbiers de *Posidonia oceanica* (Linnaeus) Delile, dans le golfe Saronikos (Mer Egée, Grèce), in: *Etude des modifications de l'écosystème dans les zones soumises à l'influence des polluants (Activité 1)*, UNEP. MAP Technical Reports 22, 85-104.
- Panayotidis, P., P. Makris and V.A. Catsiki, 1990. Cycle de bioaccumulation du Cu, Cd et Cr dans les écailles de *Posidonia oceanica*. *Rapport Commission Internationale pour l'Exploration Scientifique de la Méditerranée* 32(1), 13.
- Paterno, P., G. Cardellicchio, G. Leone, C. Marra and S. Pirano, 1991. Mercury and tin distribution in *Posidonia oceanica* (L.) Delile into the Taranto Gulf (Italy). *Oebalia* 17(1), 265-277.
- Pergent-Martini, C., 1998. *Posidonia oceanica*: a biological indicator of past and present mercury contamination in the Mediterranean Sea. *Marine Environmental Research* 45(2), 101-111.
- Pergent-Martini, C., V. Rico-Raimondino, G. Pergent, C. F. Boudouresque, J. M. Bouqueneau and A. Arnoux, 1993. *Mémorisation des métaux-traces par Posidonia oceanica*, in: C. F. Boudouresque, M. Avon and C. Pergent-Martini, *Qualité du milieu marin - Indicateurs biologiques et physico chimiques*, Rencontres scientifiques de la Côte Bleue, GIS Posidonie publ., Marseille, 3, 105-120.

- Pergent-Martini, C. and P. Guerrini, 1995. Concentration of mercury in marine phanerogam *Posidonia oceanica*, preliminary results. Rapport Commission Internationale pour l'Exploration Scientifique de la Méditerranée 34, 143.
- Pergent, G. and C. Pergent-Martini, 1999. Mercury levels and fluxes in *Posidonia oceanica* meadows. Environmental Pollution 106(1), 33-37.
- Pergent-Martini, C. and G. Pergent, 2000. Marine phanerogams as a tool in the evaluation of marine trace-metal contamination: an example from the Mediterranean. International Journal of Environment and Pollution 13(1-6), 126-147.
- Roméo, M., M. Gnassiabarelli, T. Juhel and A. Meinesz, 1995. Memorization of heavy metals by scales of the seagrass *Posidonia oceanica*, collected in the NW Mediterranean. Marine Ecology - Progress Series 120(1-3), 211-218.
- Sanchiz, C., V. Benedito, A. Pastor and A. M. Gracia-Carrascosa, 1990. Bioaccumulation of heavy metals in *Posidonia oceanica* (L.) Delile and *Cymodocea nodosa* (Ucria) Aschers at an uncontaminated site on the east coast of Spain. Rapport Commission Internationale pour l'Exploration Scientifique de la Méditerranée 32, 13.
- Sanchiz, C., A. M. Garcia-Carrascosa and A. Pastor, 2000. Heavy metal contents in soft-bottom marine macrophytes and sediments along the Mediterranean coast of Spain. Marine Ecology - Pubblicazioni della Stazioni Zoologica di Napoli 21(1), 1-16.
- Sanchiz, C., A. M. Garcia-Carrascosa and A. Pastor, 2001. Relationships between sediment physico-chemical characteristics and heavy metal bioaccumulation in Mediterranean soft-bottom macrophytes. Aquatic Botany 69(1), 63-73.
- Schlacher-Hoenlinger, M. A. and T. A. Schlacher, 1998a. Accumulation, contamination, and seasonal variability of trace metals in the coastal zone - patterns in a seagrass meadow from the Mediterranean. Marine Biology 131(3), 401-410.
- Schlacher-Hoenlinger, M. A. and T. A. Schlacher, 1998b. Differential accumulation patterns of heavy metals among the dominant macrophytes of a Mediterranean seagrass meadow. Chemosphere 37(8), 1511-1519.
- Taramelli, E., S. Costantini, R. Giordano, N. Olivieri and R. Pericardo, 1991. Cadmium in water, sediments and benthic organisms from a stretch of coast facing the thermoelectric power plant at Torvaldaliga (Civitavecchia, Rome), in: Rapports finaux sur les projets de recherches traitant de la bioaccumulation et de la toxicité des polluants chimiques, UNEP. MAP Technical Reports 52, 15-32.
- Tranchina, L., S. Bellia, M. Brai, S. Hauser, S. Rizzo, A. Bartolotta and S. Basile, 2004. Chemistry, mineralogy and radioactivity in "*Posidonia oceanica*" meadows from North-Western Sicily. Chemical Ecology 20, 203-214.
- Tranchina, L., M. Brai, F. D'Agostino, A. Bartolotta and G. Rizzo, 2005. Trace metals in *Posidonia oceanica* seagrass from south-eastern Sicily. Chemistry in Ecology 21(2), 109-118.
- Vicente, N. and D. Chabert, 1981. La pollution par les métaux lourds dans les rades du Parc National de Port-Cros. 1 - Etude préliminaire. Travaux scientifiques Parc national de Port-Cros 7, 25-34.
- Warnau, M., S. W. Fowler and J.L. Teyssie, 1996. Biokinetics of selected heavy metals and radionuclides in two marine macrophytes: the seagrass *Posidonia oceanica* and the alga *Caulerpa taxifolia*. Marine Environmental Research 41(4), 343-362.
- Warnau, M., G. Ledent, A. Temara, J. Bouqueneau, M. Jangoux and P. Dubois, 1995. Heavy metals in *Posidonia oceanica* and *Paracentrotus lividus* from seagrass beds of the north-western Mediterranean. The Science of the Total Environment 171(1-3), 95-99.

3IL		Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
PACA											
Ensuès (1)	**	0,0083 ± 0,0031	129 ± 24	9,1 ± 4,6	0,38 ± 0,06	63,5 ± 6,0	142 ± 16	2,38 ± 0,19	32,5 ± 2,7	13,3 ± 0,6	108,3 ± 8,2
La Vesse (2)	**	0,0077 ± 0,0034	114 ± 33	8,5 ± 2,7	0,30 ± 0,05	60,9 ± 4,2	121 ± 18	2,70 ± 0,18	31,4 ± 1,2	19,8 ± 2,1	169,7 ± 13,8
Corbière (3)	**	0,0078 ± 0,0027	176 ± 21	12,0 ± 3,5	0,44 ± 0,04	59,9 ± 7,3	157 ± 13	2,30 ± 0,25	30,2 ± 1,8	17,0 ± 2,0	134,8 ± 12,9
P. Chèvres (4)	**	0,0053 ± 0,0023	55 ± 8	10,1 ± 0,7	0,29 ± 0,06	44,9 ± 3,6	74 ± 6	2,13 ± 0,28	31,8 ± 2,7	11,9 ± 1,1	93,0 ± 8,4
Riou (5)		0,0013 ± 0,0017	31 ± 8	1,3 ± 0,2	0,20 ± 0,02	44,4 ± 3,6	63 ± 5	2,55 ± 0,22	38,1 ± 4,0	11,0 ± 1,0	105,2 ± 9,1
Bénat (6)	**	0,0070 ± 0,0014	74 ± 26	1,2 ± 0,2	0,21 ± 0,01	60,7 ± 4,7	87 ± 17	2,88 ± 0,30	34,9 ± 1,6	13,0 ± 1,9	101,7 ± 8,0
Giens (7)	**	0,0070 ± 0,0015	127 ± 24	1,4 ± 0,4	0,23 ± 0,03	66,7 ± 4,5	126 ± 13	3,43 ± 0,22	33,5 ± 1,7	13,0 ± 1,6	135,3 ± 4,7
Cap Roux (8)	**	0,0082 ± 0,0035	85 ± 23	8,9 ± 2,5	0,26 ± 0,01	73,7 ± 5,3	73 ± 12	3,27 ± 0,19	34,6 ± 1,9	10,0 ± 0,7	93,6 ± 5,3
St Raphaël (9)	**	0,0063 ± 0,0022	36 ± 11	3,6 ± 1,2	0,18 ± 0,03	94,6 ± 5,8	53 ± 5	4,41 ± 0,56	47,6 ± 3,7	13,3 ± 1,9	138,6 ± 11,1
Antibes (10)	**	0,0077 ± 0,0035	90 ± 31	28,0 ± 11,1	0,27 ± 0,05	57,3 ± 10,9	93 ± 15	2,51 ± 0,20	28,6 ± 1,9	13,7 ± 1,5	71,4 ± 4,3
Villefranche (11)	**	0,0071 ± 0,0027	57 ± 11	13,6 ± 3,6	0,29 ± 0,02	72,2 ± 20,0	85 ± 6	2,06 ± 0,29	20,5 ± 1,5	23,6 ± 1,7	90,6 ± 13,7
Corsica											
Calvi (I)		0,0015 ± 0,0014	20 ± 4	9,1 ± 2,2	0,15 ± 0,01	47,9 ± 5,6	45 ± 6	1,79 ± 0,12	27,8 ± 1,7	7,2 ± 1,2	73,4 ± 7,5
Aregno (II)		0,0009 ± 0,0028	36 ± 12	0,9 ± 0,1	0,14 ± 0,02	52,0 ± 2,5	55 ± 6	2,79 ± 0,09	28,7 ± 0,8	14,6 ± 1,0	114,5 ± 9,4
St Florent (III)		0,0041 ± 0,0018	96 ± 23	3,1 ± 0,8	0,93 ± 0,24	45,0 ± 1,9	139 ± 23	2,02 ± 0,14	25,1 ± 1,0	8,7 ± 1,3	79,6 ± 8,2
T. Isolaccio (IV)	**	0,0087 ± 0,0032	122 ± 8	16,8 ± 6,5	0,50 ± 0,07	89,7 ± 13,7	134 ± 14	2,43 ± 0,25	28,6 ± 3,2	11,0 ± 0,8	107,3 ± 15,3
Bravone (V)	**	0,0093 ± 0,0027	165 ± 111	1,7 ± 0,2	0,52 ± 0,08	72,1 ± 9,5	150 ± 34	3,42 ± 0,24	27,9 ± 2,6	21,6 ± 2,3	1114,9 ± 320,1
Ajaccio S. (VI)		0,0042 ± 0,0038	55 ± 11	3,1 ± 1,4	0,20 ± 0,03	57,6 ± 3,1	66 ± 4	2,85 ± 0,17	39,8 ± 0,8	8,2 ± 0,2	102,2 ± 7,5
Ajaccio N. (VII)	**	0,0099 ± 0,0036	132 ± 44	5,6 ± 2,0	0,26 ± 0,02	58,2 ± 3,1	149 ± 31	1,75 ± 0,09	23,7 ± 1,0	7,8 ± 1,0	84,5 ± 9,5
OIL		Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
PACA											
Ensuès (1)	**	0,0092 ± 0,0035	128 ± 30	9,0 ± 3,6	0,37 ± 0,05	66,7 ± 2,9	145 ± 15	2,51 ± 0,16	25,3 ± 1,6	13,9 ± 0,8	119,5 ± 8,8
La Vesse (2)	**	0,0068 ± 0,0023	99 ± 16	12,5 ± 5,4	0,29 ± 0,03	65,2 ± 3,2	114 ± 7	2,76 ± 0,11	26,2 ± 1,0	20,6 ± 0,8	174,2 ± 11,1
Corbière (3)	*	0,0106 ± 0,0022	140 ± 40	11,5 ± 2,4	0,35 ± 0,06	61,4 ± 6,8	136 ± 24	2,40 ± 0,16	22,9 ± 1,3	18,5 ± 1,2	152,5 ± 5,9
P. Chèvres (4)		0,0050 ± 0,0035	62 ± 12	8,3 ± 1,3	0,27 ± 0,03	42,2 ± 2,2	80 ± 7	1,91 ± 0,11	23,2 ± 1,1	11,9 ± 0,7	90,8 ± 6,6
Riou (5)		0,0026 ± 0,0023	25 ± 8	1,2 ± 0,1	0,14 ± 0,03	39,3 ± 2,3	56 ± 4	2,11 ± 0,18	27,8 ± 2,8	10,9 ± 0,9	92,7 ± 7,2
Bénat (6)	**	0,0066 ± 0,0047	81 ± 31	1,4 ± 0,2	0,17 ± 0,02	56,2 ± 3,5	87 ± 16	2,34 ± 0,25	26,8 ± 2,9	12,5 ± 1,7	87,2 ± 4,1
Giens (7)	**	0,0066 ± 0,0024	130 ± 42	1,1 ± 0,4	0,18 ± 0,03	58,2 ± 4,7	122 ± 22	2,79 ± 0,30	27,5 ± 1,8	13,9 ± 1,3	110,7 ± 7,2
Cap Roux (8)		0,0049 ± 0,0035	88 ± 31	4,5 ± 0,9	0,15 ± 0,01	64,7 ± 5,7	64 ± 8	2,65 ± 0,15	24,4 ± 1,7	11,2 ± 1,3	85,5 ± 4,5
St Raphaël (9)		0,0051 ± 0,0019	38 ± 10	2,7 ± 0,8	0,16 ± 0,04	84,3 ± 6,2	57 ± 18	3,81 ± 0,26	38,7 ± 2,0	13,6 ± 1,1	120,6 ± 8,6
Antibes (10)		0,0033 ± 0,0019	74 ± 5	23,7 ± 8,2	0,19 ± 0,01	49,9 ± 4,4	78 ± 3	2,18 ± 0,09	21,9 ± 1,6	13,6 ± 1,0	67,4 ± 2,8
Villefranche (11)		0,0051 ± 0,0035	57 ± 14	11,2 ± 5,3	0,22 ± 0,02	55,5 ± 14,6	76 ± 7	1,59 ± 0,13	13,9 ± 1,9	22,4 ± 2,6	80,9 ± 1,6
Corsica											
Calvi (I)	**	0,0068 ± 0,0038	17 ± 6	7,2 ± 2,4	0,13 ± 0,03	44,2 ± 2,1	41 ± 2	1,59 ± 0,08	23,9 ± 1,6	7,3 ± 0,6	73,7 ± 8,2
Aregno (II)	*	0,0118 ± 0,0035	98 ± 43	0,8 ± 0,1	0,17 ± 0,06	43,8 ± 3,4	76 ± 18	2,27 ± 0,20	23,8 ± 1,6	17,4 ± 2,8	99,8 ± 7,7
St Florent (III)		0,0050 ± 0,0019	86 ± 14	2,3 ± 0,6	0,82 ± 0,15	38,0 ± 2,3	119 ± 13	1,57 ± 0,09	20,0 ± 0,8	9,1 ± 0,8	74,2 ± 11,9
T. Isolaccio (IV)	**	0,0074 ± 0,0034	102 ± 35	12,4 ± 3,4	0,37 ± 0,11	62,4 ± 1,4	115 ± 24	1,68 ± 0,07	22,5 ± 0,8	11,1 ± 0,8	82,4 ± 14,0
Bravone (V)	**	0,0065 ± 0,0022	110 ± 46	1,6 ± 0,3	0,54 ± 0,26	61,1 ± 4,7	202 ± 91	3,09 ± 0,21	24,5 ± 2,2	22,7 ± 1,5	1332,0 ± 333,3
Ajaccio S. (VI)	**	0,0073 ± 0,0034	67 ± 21	2,2 ± 0,5	0,14 ± 0,01	51,5 ± 3,4	62 ± 5	2,24 ± 0,14	26,8 ± 0,7	8,2 ± 0,5	92,2 ± 12,0
Ajaccio N. (VII)	**	0,0086 ± 0,0042	121 ± 41	9,0 ± 7,7	0,19 ± 0,04	51,2 ± 8,0	122 ± 10	1,35 ± 0,20	19,4 ± 1,4	7,1 ± 0,5	76,3 ± 9,7

Annex B. Spatial variation of trace element concentrations in *Posidonia oceanica* 3rd intermediate leaves (3IL; n = 3-5), other intermediate leaves (OIL; n = 5), blades of adult leaves (BAL; n = 4-5) and sheaths of adult leaves (SAL; n = 3-5). Concentrations are expressed as mean ± standard deviation in µg.g⁻¹_{DW}. *, **, struck-through values and nd represent concentrations < L_Q, < L_D, < L_C and not detected, respectively. Number of replicates varies from 3 to 5, depending on site and compartment.

3IL	As		Se	Mo	Ag	Cd		Sn	Sb	Pb	Bi
PACA											
Ensuès (1)	3,72 ± 1,09		0,301 ± 0,035	1,61 ± 0,40	0,98 ± 0,14	2,29 ± 0,15		0,005 ± 0,006	0,173 ± 0,012	2,40 ± 0,23	0,0158 ± 0,0019
La Vesse (2)	1,89 ± 0,19	*	0,272 ± 0,024	1,14 ± 0,13	1,66 ± 0,20	2,64 ± 0,15	*	0,024 ± 0,010	0,143 ± 0,022	3,24 ± 0,27	0,0221 ± 0,0022
Corbière (3)	2,50 ± 0,38	*	0,223 ± 0,036	1,54 ± 0,17	0,84 ± 0,05	1,92 ± 0,09	*	0,056 ± 0,022	0,211 ± 0,041	4,05 ± 0,33	0,0230 ± 0,0021
P. Chèvres (4)	7,51 ± 0,64	*	0,233 ± 0,039	1,63 ± 0,13	1,03 ± 0,09	2,44 ± 0,26		0,005 ± 0,009	0,190 ± 0,021	2,69 ± 1,10	0,0403 ± 0,0111
Riou (5)	1,83 ± 0,16	*	0,224 ± 0,038	1,30 ± 0,14	1,08 ± 0,16	3,28 ± 0,14		nd	0,181 ± 0,015	1,36 ± 0,28	0,0145 ± 0,0035
Bénat (6)	1,25 ± 0,12	*	0,242 ± 0,035	1,62 ± 0,20	1,01 ± 0,12	3,09 ± 0,19		nd	0,196 ± 0,045	1,10 ± 0,04	0,0052 ± 0,0013
Giens (7)	0,94 ± 0,12	*	0,261 ± 0,023	1,32 ± 0,10	0,98 ± 0,09	3,26 ± 0,16		nd	0,194 ± 0,016	1,38 ± 0,16	0,0049 ± 0,0007
Cap Roux (8)	1,73 ± 0,43	*	0,229 ± 0,065	1,81 ± 0,16	0,84 ± 0,10	3,04 ± 0,16		nd	0,239 ± 0,025	1,45 ± 0,65	0,0093 ± 0,0020
St Raphaël (9)	1,10 ± 0,13		0,332 ± 0,041	1,67 ± 0,50	1,16 ± 0,20	4,53 ± 0,43	**	0,015 ± 0,095	0,193 ± 0,051	1,00 ± 0,18	0,0042 ± 0,0008
Antibes (10)	2,58 ± 0,35		0,326 ± 0,044	4,56 ± 2,53	0,81 ± 0,08	2,26 ± 0,08		nd	0,204 ± 0,026	1,08 ± 0,20	0,0079 ± 0,0017
Villefranche (11)	1,71 ± 0,09	*	0,242 ± 0,056	6,22 ± 4,26	0,70 ± 0,09	1,19 ± 0,09	*	0,026 ± 0,013	0,252 ± 0,037	3,85 ± 0,78	0,0205 ± 0,0034
Corsica											
Calvi (I)	2,80 ± 0,31		0,324 ± 0,048	5,80 ± 1,88	0,61 ± 0,03	2,70 ± 0,10		nd	0,147 ± 0,010	1,36 ± 0,28	0,0054 ± 0,0005
Aregno (II)	0,89 ± 0,03		0,296 ± 0,088	5,24 ± 2,94	1,28 ± 0,16	3,94 ± 0,12		nd	0,142 ± 0,020	0,91 ± 0,07	0,0035 ± 0,0004
St Florent (III)	0,93 ± 0,07	*	0,146 ± 0,044	1,69 ± 0,25	0,53 ± 0,04	1,72 ± 0,05		nd	0,180 ± 0,020	1,95 ± 0,34	0,0066 ± 0,0008
T. Isolaccio (IV)	1,15 ± 0,20	*	0,227 ± 0,052	4,23 ± 1,26	0,75 ± 0,03	2,27 ± 0,15		nd	0,200 ± 0,019	1,13 ± 0,18	0,0064 ± 0,0008
Bravone (V)	0,98 ± 0,05	*	0,156 ± 0,032	1,62 ± 0,19	1,10 ± 0,11	2,70 ± 0,23	*	0,028 ± 0,016	0,658 ± 0,158	2,20 ± 0,59	0,0049 ± 0,0006
Ajaccio S. (VI)	2,18 ± 0,15	*	0,272 ± 0,045	2,80 ± 0,46	1,23 ± 0,17	2,66 ± 0,09	**	0,019 ± 0,019	0,200 ± 0,014	2,38 ± 0,85	0,0083 ± 0,0016
Ajaccio N. (VII)	1,65 ± 0,12	*	0,152 ± 0,030	2,49 ± 0,50	0,56 ± 0,04	1,68 ± 0,08	*	0,023 ± 0,017	0,212 ± 0,016	5,77 ± 2,02	0,0142 ± 0,0031
OIL	As		Se	Mo	Ag	Cd		Sn	Sb	Pb	Bi
PACA											
Ensuès (1)	3,28 ± 0,23	**	0,343 ± 0,032	1,86 ± 0,30	1,06 ± 0,06	2,36 ± 0,08	*	0,048 ± 0,008	0,205 ± 0,019	2,49 ± 0,23	0,0158 ± 0,0015
La Vesse (2)	1,93 ± 0,14	**	0,306 ± 0,029	1,14 ± 0,06	1,80 ± 0,21	2,68 ± 0,17	*	0,062 ± 0,006	0,161 ± 0,010	3,25 ± 0,23	0,0212 ± 0,0011
Corbière (3)	2,42 ± 0,19	**	0,272 ± 0,037	1,68 ± 0,30	0,98 ± 0,10	2,05 ± 0,13	*	0,085 ± 0,016	0,240 ± 0,014	3,64 ± 0,22	0,0196 ± 0,0015
P. Chèvres (4)	7,54 ± 0,67	**	0,285 ± 0,036	1,83 ± 0,65	1,12 ± 0,13	2,31 ± 0,14	**	0,024 ± 0,013	0,176 ± 0,011	2,44 ± 0,34	0,0431 ± 0,0040
Riou (5)	1,62 ± 0,11		0,222 ± 0,027	1,14 ± 0,05	1,11 ± 0,08	2,97 ± 0,13		0,009 ± 0,005	0,162 ± 0,017	1,08 ± 0,18	0,0103 ± 0,0007
Bénat (6)	1,15 ± 0,12		0,243 ± 0,039	1,55 ± 0,31	1,09 ± 0,19	2,75 ± 0,18		0,005 ± 0,003	0,178 ± 0,035	1,03 ± 0,13	0,0046 ± 0,0015
Giens (7)	0,83 ± 0,08	**	0,272 ± 0,027	1,18 ± 0,15	1,14 ± 0,07	2,81 ± 0,17		0,004 ± 0,003	0,148 ± 0,008	1,17 ± 0,14	0,0045 ± 0,0004
Cap Roux (8)	1,22 ± 0,08		0,159 ± 0,038	1,63 ± 0,07	1,05 ± 0,13	2,90 ± 0,24		0,010 ± 0,003	0,184 ± 0,016	0,86 ± 0,04	0,0037 ± 0,0003
St Raphaël (9)	1,07 ± 0,11	**	0,268 ± 0,036	1,63 ± 0,29	1,27 ± 0,08	4,17 ± 0,26		0,000 ± 0,004	0,170 ± 0,010	0,91 ± 0,08	0,0045 ± 0,0012
Antibes (10)	2,33 ± 0,13	**	0,269 ± 0,035	3,26 ± 0,64	0,82 ± 0,07	2,09 ± 0,08		0,006 ± 0,011	0,181 ± 0,013	0,89 ± 0,09	0,0077 ± 0,0014
Villefranche (11)	1,61 ± 0,15		0,234 ± 0,026	3,86 ± 2,76	0,69 ± 0,03	1,07 ± 0,06	*	0,038 ± 0,021	0,219 ± 0,010	3,03 ± 0,60	0,0177 ± 0,0029
Corsica											
Calvi (I)	2,58 ± 0,26	**	0,356 ± 0,019	5,44 ± 1,42	0,67 ± 0,05	2,63 ± 0,08		nd	0,170 ± 0,018	1,44 ± 0,36	0,0044 ± 0,0004
Aregno (II)	0,92 ± 0,05	**	0,282 ± 0,054	5,70 ± 4,75	1,50 ± 0,17	3,50 ± 0,05	**	0,035 ± 0,048	0,126 ± 0,020	0,88 ± 0,20	0,0027 ± 0,0003
St Florent (III)	0,85 ± 0,05		0,230 ± 0,031	1,56 ± 0,35	0,66 ± 0,05	1,62 ± 0,09		0,005 ± 0,009	0,143 ± 0,008	1,46 ± 0,25	0,0050 ± 0,0008
T. Isolaccio (IV)	0,99 ± 0,11		0,199 ± 0,039	2,59 ± 0,69	0,94 ± 0,05	2,05 ± 0,15		0,004 ± 0,002	0,153 ± 0,009	0,75 ± 0,05	0,0062 ± 0,0017
Bravone (V)	1,21 ± 0,32		0,184 ± 0,045	1,49 ± 0,13	1,24 ± 0,15	2,72 ± 0,08	*	0,062 ± 0,017	0,705 ± 0,156	2,43 ± 0,61	0,0045 ± 0,0012
Ajaccio S. (VI)	1,95 ± 0,29	**	0,311 ± 0,084	3,22 ± 0,87	1,29 ± 0,16	2,59 ± 0,12	*	0,039 ± 0,013	0,206 ± 0,049	1,78 ± 0,59	0,0075 ± 0,0015
Ajaccio N. (VII)	1,66 ± 0,15	**	0,267 ± 0,022	2,69 ± 0,38	0,58 ± 0,04	1,59 ± 0,13	*	0,044 ± 0,026	0,191 ± 0,020	4,51 ± 1,46	0,0114 ± 0,0031

Annex B (Continued). Spatial variation of trace element concentrations in *Posidonia oceanica* 3rd intermediate leaves (3IL; n = 3-5), other intermediate leaves (OIL; n = 5), blades of adult leaves (BAL; n = 4-5) and sheaths of adult leaves (SAL; n = 3-5). Concentrations are expressed as mean ± standard deviation in µg.g⁻¹_{DW}. *, **, struck-through values and nd represent concentrations < L_Q, < L_D, < L_C and not detected, respectively. Number of replicates varies from 3 to 5, depending on site and compartment.

BAL		Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
PACA											
Ensuès (1)		0,0102 ± 0,0013	91 ± 21	12,3 ± 2,1	0,36 ± 0,05	72,4 ± 2,3	121 ± 25	2,74 ± 0,15	36,5 ± 1,8	10,1 ± 0,7	100,5 ± 4,3
La Vesse (2)		0,0105 ± 0,0043	132 ± 50	15,0 ± 3,3	0,40 ± 0,10	78,9 ± 8,3	133 ± 27	3,48 ± 0,26	42,7 ± 4,2	17,4 ± 1,1	156,8 ± 7,8
Corbière (3)		0,0103 ± 0,0028	123 ± 25	20,1 ± 8,0	0,40 ± 0,07	67,4 ± 10,6	132 ± 18	2,76 ± 0,39	35,0 ± 3,6	17,1 ± 1,8	135,0 ± 11,6
P. Chèvres (4)	*	0,0088 ± 0,0018	65 ± 7	40,1 ± 7,3	0,47 ± 0,01	58,1 ± 3,6	88 ± 6	2,76 ± 0,12	37,4 ± 1,7	11,7 ± 0,6	103,5 ± 4,2
Riou (5)	*	0,0069 ± 0,0035	21 ± 6	2,6 ± 0,3	0,20 ± 0,02	50,2 ± 6,5	54 ± 7	2,89 ± 0,29	42,5 ± 1,7	9,3 ± 1,1	99,2 ± 9,3
Bénat (6)	*	0,0094 ± 0,0026	88 ± 26	2,6 ± 0,3	0,27 ± 0,05	79,0 ± 7,6	95 ± 8	3,90 ± 0,54	45,1 ± 6,3	11,2 ± 2,2	100,3 ± 12,4
Giens (7)		0,0119 ± 0,0030	154 ± 30	2,7 ± 1,0	0,31 ± 0,04	90,7 ± 5,6	137 ± 21	4,52 ± 0,41	45,9 ± 2,2	10,6 ± 1,1	143,1 ± 6,8
Cap Roux (8)		0,0139 ± 0,0017	156 ± 25	12,8 ± 2,6	0,35 ± 0,02	93,7 ± 10,4	89 ± 6	4,26 ± 0,42	46,7 ± 4,0	8,1 ± 0,7	95,0 ± 6,6
St Raphaël (9)	*	0,0091 ± 0,0022	41 ± 12	4,5 ± 1,3	0,26 ± 0,04	118,4 ± 17,3	53 ± 7	6,17 ± 0,77	66,0 ± 5,6	10,4 ± 1,6	138,2 ± 14,9
Antibes (10)		0,0114 ± 0,0019	114 ± 38	24,3 ± 8,6	0,36 ± 0,06	61,0 ± 6,9	98 ± 17	3,12 ± 0,24	38,8 ± 3,4	12,5 ± 1,3	69,6 ± 7,8
Villefranche (11)		0,0122 ± 0,0032	60 ± 7	16,4 ± 5,9	0,36 ± 0,03	65,4 ± 12,0	96 ± 5	2,86 ± 0,27	30,2 ± 3,8	22,1 ± 1,2	98,4 ± 3,0
Corsica											
Calvi (I)	*	0,0083 ± 0,0012	20 ± 4	12,8 ± 1,9	0,23 ± 0,02	63,3 ± 7,4	43 ± 2	2,71 ± 0,08	36,5 ± 1,5	5,9 ± 0,4	76,7 ± 4,6
Aregno (II)		0,0026 ± 0,0024	39 ± 12	2,2 ± 0,3	0,19 ± 0,02	73,5 ± 3,5	53 ± 4	4,37 ± 0,16	40,4 ± 1,9	13,6 ± 1,4	133,2 ± 9,1
St Florent (III)	**	0,0033 ± 0,0027	89 ± 36	3,7 ± 0,6	0,90 ± 0,22	63,1 ± 7,4	136 ± 35	2,85 ± 0,05	31,6 ± 2,8	8,1 ± 1,2	79,0 ± 6,1
T. Isolaccio (IV)		0,0111 ± 0,0028	84 ± 18	29,3 ± 9,7	0,49 ± 0,07	129,1 ± 15,8	109 ± 11	3,39 ± 0,21	38,1 ± 1,2	8,8 ± 0,9	100,9 ± 15,1
Bravone (V)		0,0124 ± 0,0015	146 ± 31	3,6 ± 0,5	0,54 ± 0,04	111,9 ± 9,9	148 ± 19	5,22 ± 0,19	40,4 ± 2,1	22,6 ± 2,6	1655,0 ± 337,9
Ajaccio S. (VI)	*	0,0060 ± 0,0020	92 ± 22	5,2 ± 1,5	0,25 ± 0,05	69,8 ± 5,1	83 ± 10	3,52 ± 0,22	42,4 ± 2,1	8,2 ± 0,4	97,3 ± 7,8
Ajaccio N. (VII)		0,0144 ± 0,0035	168 ± 61	7,3 ± 3,1	0,31 ± 0,06	72,6 ± 11,1	157 ± 26	2,11 ± 0,18	26,3 ± 1,9	6,8 ± 0,3	74,4 ± 3,5
SAL		Be	Al	V	Cr	Mn	Fe	Co	Ni	Cu	Zn
PACA											
Ensuès (1)		0,0080 ± 0,0002	161 ± 20	1,7 ± 0,4	0,40 ± 0,08	18,4 ± 0,6	193 ± 15	0,32 ± 0,03	16,5 ± 0,2	19,9 ± 0,3	48,9 ± 7,1
La Vesse (2)		0,0042 ± 0,0000	95 ± 5	2,2 ± 1,3	0,25 ± 0,04	18,4 ± 0,7	105 ± 5	0,30 ± 0,03	13,3 ± 0,7	27,5 ± 3,1	55,0 ± 4,5
Corbière (3)		0,0043 ± 0,0000	119 ± 33	1,1 ± 0,1	0,23 ± 0,06	14,8 ± 0,3	113 ± 20	0,25 ± 0,03	11,7 ± 0,7	22,8 ± 2,4	47,3 ± 0,6
P. Chèvres (4)		0,0042 ± 0,0000	74 ± 13	2,2 ± 0,1	0,37 ± 0,10	16,8 ± 1,9	89 ± 7	0,30 ± 0,04	14,9 ± 1,0	13,5 ± 0,5	46,0 ± 2,3
Riou (5)		0,0035 ± 0,0009	38 ± 8	0,8 ± 0,2	0,19 ± 0,01	12,5 ± 0,3	56 ± 12	0,26 ± 0,04	18,2 ± 0,4	16,4 ± 0,5	43,3 ± 2,0
Bénat (6)		0,0057 ± 0,0024	154 ± 44	0,6 ± 0,1	0,19 ± 0,07	12,2 ± 0,2	127 ± 45	0,27 ± 0,03	16,0 ± 2,7	17,6 ± 0,1	28,2 ± 0,2
Giens (7)		0,0061 ± 0,0018	211 ± 31	0,9 ± 0,2	0,25 ± 0,03	15,4 ± 1,6	197 ± 31	0,27 ± 0,03	11,2 ± 2,1	19,1 ± 3,2	30,1 ± 1,5
Cap Roux (8)		0,0059 ± 0,0017	153 ± 43	0,7 ± 0,2	0,14 ± 0,03	14,7 ± 2,1	74 ± 16	0,25 ± 0,02	10,2 ± 0,9	14,3 ± 1,4	24,8 ± 1,4
St Raphaël (9)		0,0038 ± 0,0020	70 ± 22	0,8 ± 0,2	0,19 ± 0,06	20,4 ± 4,5	64 ± 15	0,41 ± 0,09	17,5 ± 2,5	16,8 ± 2,3	35,2 ± 3,2
Antibes (10)		0,0035 ± 0,0017	98 ± 18	2,2 ± 1,2	0,20 ± 0,04	15,0 ± 2,5	100 ± 13	0,30 ± 0,04	12,3 ± 0,2	22,5 ± 2,3	33,6 ± 2,8
Villefranche (11)		0,0014 ± 0,0023	75 ± 10	1,0 ± 0,4	0,48 ± 0,50	8,2 ± 1,1	78 ± 4	0,22 ± 0,01	9,3 ± 0,3	25,6 ± 3,2	27,5 ± 0,5
Corsica											
Calvi (I)		0,0024 ± 0,0022	29 ± 7	0,5 ± 0,1	0,07 ± 0,01	8,3 ± 0,8	28 ± 5	0,27 ± 0,01	15,9 ± 3,1	8,2 ± 1,9	28,4 ± 3,6
Aregno (II)		0,0096 ± 0,0062	164 ± 96	1,1 ± 0,5	0,54 ± 0,46	9,2 ± 1,7	138 ± 103	0,24 ± 0,04	12,7 ± 2,1	17,0 ± 1,5	24,3 ± 2,9
St Florent (III)		0,0053 ± 0,0023	223 ± 10	1,1 ± 0,3	1,87 ± 0,24	10,4 ± 0,7	182 ± 19	0,26 ± 0,01	11,6 ± 1,5	14,2 ± 1,1	33,4 ± 3,5
T. Isolaccio (IV)		0,0069 ± 0,0024	277 ± 61	2,7 ± 1,3	0,98 ± 0,15	28,3 ± 4,2	315 ± 56	0,38 ± 0,08	11,3 ± 2,1	15,2 ± 2,0	30,2 ± 4,7
Bravone (V)		0,0050 ± 0,0035	219 ± 49	1,0 ± 0,2	0,95 ± 0,25	17,1 ± 2,5	251 ± 56	0,42 ± 0,05	8,8 ± 1,0	24,3 ± 3,5	356,5 ± 239,2
Ajaccio S. (VI)		0,0194 ± 0,0089	417 ± 178	2,0 ± 0,6	0,24 ± 0,06	16,0 ± 3,0	145 ± 59	0,30 ± 0,05	13,8 ± 1,0	9,7 ± 1,4	30,8 ± 1,3
Ajaccio N. (VII)		0,0122 ± 0,0002	212 ± 33	1,8 ± 1,3	0,15 ± 0,03	13,8 ± 1,3	146 ± 28	0,20 ± 0,03	11,4 ± 1,3	9,7 ± 1,9	29,7 ± 3,7

Annex B (Continued). Spatial variation of trace element concentrations in *Posidonia oceanica* 3rd intermediate leaves (3IL; n = 3-5), other intermediate leaves (OIL; n = 5), blades of adult leaves (BAL; n = 4-5) and sheaths of adult leaves (SAL; n = 3-5). Concentrations are expressed as mean ± standard deviation in µg.g⁻¹_{DW}. *, **, struck-through values and nd represent concentrations < L_Q, < L_D, < L_C and not detected, respectively. Number of replicates varies from 3 to 5, depending on site and compartment.

BAL	As	Se	Mo	Ag	Cd	Sn	Sb	Pb	Bi
PACA									
Ensues (1)	3,76 ± 0,52	0,285 ± 0,043	1,63 ± 0,28	0,56 ± 0,11	1,99 ± 0,12	* 0,041 ± 0,013	0,227 ± 0,010	3,21 ± 0,23	0,0207 ± 0,0011
La Vesse (2)	2,57 ± 0,37	0,288 ± 0,055	1,33 ± 0,14	1,36 ± 0,10	2,35 ± 0,11	0,105 ± 0,018	0,199 ± 0,007	6,08 ± 0,74	0,0393 ± 0,0052
Corbière (3)	2,81 ± 0,27	0,240 ± 0,047	1,95 ± 0,20	0,89 ± 0,17	1,49 ± 0,11	0,115 ± 0,030	0,257 ± 0,039	6,12 ± 1,12	0,0320 ± 0,0045
P. Chèvres (4)	13,97 ± 2,22	0,386 ± 0,051	4,16 ± 3,16	0,59 ± 0,06	1,97 ± 0,09	0,055 ± 0,014	0,239 ± 0,009	5,81 ± 0,58	0,0700 ± 0,0044
Riou (5)	2,01 ± 0,22	0,231 ± 0,059	1,40 ± 0,28	0,70 ± 0,11	2,95 ± 0,20	* 0,017 ± 0,008	0,216 ± 0,021	1,82 ± 0,28	0,0181 ± 0,0026
Bénat (6)	1,46 ± 0,14	0,220 ± 0,033	2,03 ± 0,45	0,95 ± 0,19	3,21 ± 0,36	* 0,024 ± 0,004	0,232 ± 0,029	1,83 ± 0,20	0,0067 ± 0,0007
Giens (7)	1,15 ± 0,08	0,178 ± 0,018	1,46 ± 0,17	0,75 ± 0,03	3,35 ± 0,19	* 0,026 ± 0,004	0,232 ± 0,016	2,28 ± 0,27	0,0066 ± 0,0010
Cap Roux (8)	2,15 ± 0,17	0,217 ± 0,031	2,04 ± 0,22	0,55 ± 0,04	3,05 ± 0,26	* 0,037 ± 0,012	0,272 ± 0,024	1,77 ± 0,14	0,0081 ± 0,0013
St Raphaël (9)	1,34 ± 0,14	0,315 ± 0,065	1,78 ± 0,29	0,72 ± 0,09	4,67 ± 0,48	* 0,020 ± 0,003	0,233 ± 0,029	1,52 ± 0,26	0,0067 ± 0,0009
Antibes (10)	3,59 ± 0,67	0,297 ± 0,024	3,28 ± 1,32	0,74 ± 0,08	2,29 ± 0,16	* 0,027 ± 0,005	0,238 ± 0,021	1,80 ± 0,24	0,0118 ± 0,0021
Villefranche (11)	2,00 ± 0,21	0,257 ± 0,045	3,81 ± 1,58	0,75 ± 0,11	1,22 ± 0,07	0,098 ± 0,009	0,331 ± 0,024	5,48 ± 1,07	0,0379 ± 0,0041
Corsica									
Calvi (I)	3,57 ± 0,58	0,331 ± 0,036	6,31 ± 1,80	0,40 ± 0,06	2,64 ± 0,13	* 0,019 ± 0,003	0,249 ± 0,015	2,03 ± 0,20	0,0082 ± 0,0007
Aregno (II)	1,05 ± 0,02	0,330 ± 0,038	47,63 ± 25,51	0,64 ± 0,03	4,40 ± 0,10	* 0,023 ± 0,029	0,262 ± 0,008	1,45 ± 0,08	* 0,0047 ± 0,0006
St Florent (III)	1,01 ± 0,12	0,194 ± 0,045	1,52 ± 0,14	0,41 ± 0,03	1,89 ± 0,11	* 0,026 ± 0,011	0,255 ± 0,127	3,00 ± 0,61	0,0089 ± 0,0022
T. Isolaccio (IV)	1,38 ± 0,29	0,244 ± 0,086	3,79 ± 1,90	0,46 ± 0,05	2,54 ± 0,15	* 0,025 ± 0,011	0,225 ± 0,020	1,76 ± 0,13	0,0085 ± 0,0008
Bravone (V)	1,25 ± 0,11	0,239 ± 0,027	1,93 ± 0,26	1,02 ± 0,08	2,63 ± 0,09	0,059 ± 0,040	0,875 ± 0,178	3,47 ± 0,60	0,0073 ± 0,0005
Ajaccio S. (VI)	2,55 ± 0,22	0,274 ± 0,019	4,21 ± 0,84	0,83 ± 0,08	2,63 ± 0,28	0,072 ± 0,060	0,247 ± 0,019	3,13 ± 0,53	0,0153 ± 0,0027
Ajaccio N. (VII)	2,07 ± 0,19	0,184 ± 0,023	2,60 ± 0,22	0,41 ± 0,06	1,75 ± 0,05	0,080 ± 0,032	0,228 ± 0,034	5,91 ± 0,79	0,0185 ± 0,0029
SAL	As	Se	Mo	Ag	Cd	Sn	Sb	Pb	Bi
PACA									
Ensues (1)	2,89 ± 0,27	0,162 ± 0,009	0,77 ± 0,14	1,56 ± 0,14	1,34 ± 0,12	nd	* 0,019 ± 0,007	0,83 ± 0,05	* 0,0072 ± 0,0016
La Vesse (2)	1,74 ± 0,33	0,109 ± 0,058	0,78 ± 0,27	2,07 ± 0,12	0,84 ± 0,03	nd	* 0,022 ± 0,010	1,09 ± 0,13	* 0,0077 ± 0,0009
Corbière (3)	2,28 ± 0,20	0,095 ± 0,029	0,57 ± 0,00	1,16 ± 0,00	0,87 ± 0,03	nd	* 0,016 ± 0,008	1,23 ± 0,12	* 0,0070 ± 0,0013
P. Chèvres (4)	8,34 ± 2,36	0,156 ± 0,009	0,82 ± 0,09	1,32 ± 0,05	1,40 ± 0,07	0,007 ± 0,009	* 0,023 ± 0,000	1,08 ± 0,13	0,0248 ± 0,0003
Riou (5)	1,09 ± 0,17	0,098 ± 0,003	0,57 ± 0,07	1,55 ± 0,12	1,86 ± 0,04	nd	** 0,011 ± 0,001	0,60 ± 0,09	* 0,0078 ± 0,0020
Bénat (6)	0,95 ± 0,10	0,159 ± 0,034	0,78 ± 0,23	1,22 ± 0,02	1,23 ± 0,03	nd	** 0,011 ± 0,005	0,40 ± 0,18	0,0002 ± 0,0006
Giens (7)	0,74 ± 0,18	0,107 ± 0,019	0,69 ± 0,07	1,44 ± 0,04	1,21 ± 0,09	nd	* 0,017 ± 0,008	0,64 ± 0,10	0,0010 ± 0,0006
Cap Roux (8)	0,95 ± 0,19	0,092 ± 0,022	0,79 ± 0,07	1,12 ± 0,13	1,68 ± 0,19	nd	** 0,009 ± 0,003	0,40 ± 0,05	** 0,0029 ± 0,0015
St Raphaël (9)	0,93 ± 0,16	0,147 ± 0,021	1,03 ± 0,16	1,44 ± 0,12	1,94 ± 0,09	nd	* 0,022 ± 0,020	0,51 ± 0,15	* 0,0047 ± 0,0012
Antibes (10)	1,82 ± 0,41	0,059 ± 0,015	0,81 ± 0,24	1,25 ± 0,05	1,33 ± 0,06	nd	* 0,016 ± 0,004	0,43 ± 0,06	** 0,0030 ± 0,0006
Villefranche (11)	1,81 ± 0,18	0,071 ± 0,051	0,63 ± 0,04	0,65 ± 0,05	0,52 ± 0,08	nd	** 0,011 ± 0,002	0,99 ± 0,06	* 0,0070 ± 0,0009
Corsica									
Calvi (I)	1,42 ± 0,21	0,130 ± 0,049	0,61 ± 0,10	0,69 ± 0,04	1,19 ± 0,13	nd ±	nd	0,30 ± 0,16	0,0011 ± 0,0004
Aregno (II)	0,84 ± 0,14	0,155 ± 0,025	5,63 ± 4,45	1,38 ± 0,17	1,32 ± 0,15	0,120 ± 0,264	0,004 ± 0,013	0,32 ± 0,17	0,0011 ± 0,0003
St Florent (III)	0,53 ± 0,05	0,188 ± 0,008	0,42 ± 0,02	0,83 ± 0,09	0,86 ± 0,12	nd ±	nd	0,48 ± 0,18	** 0,0025 ± 0,0011
T. Isolaccio (IV)	1,27 ± 0,22	nd	1,00 ± 0,22	1,21 ± 0,10	1,10 ± 0,05	nd ±	* 0,014 ± 0,011	0,45 ± 0,06	0,0018 ± 0,0007
Bravone (V)	1,25 ± 0,31	0,048 ± 0,025	0,61 ± 0,11	1,30 ± 0,15	1,05 ± 0,07	** 0,012 ± 0,041	0,228 ± 0,127	0,77 ± 0,22	** 0,0035 ± 0,0006
Ajaccio S. (VI)	1,77 ± 0,34	0,177 ± 0,077	2,17 ± 1,57	1,60 ± 0,23	1,04 ± 0,07	** 0,014 ± 0,020	* 0,014 ± 0,003	0,68 ± 0,17	* 0,0054 ± 0,0023
Ajaccio N. (VII)	0,81 ± 0,12	** 0,220 ± 0,024	0,93 ± 0,16	0,64 ± 0,04	0,75 ± 0,06	** 0,018 ± 0,021	* 0,018 ± 0,009	0,90 ± 0,28	** 0,0031 ± 0,0013

Annex B (Continued). Spatial variation of trace element concentrations in *Posidonia oceanica* 3rd intermediate leaves (3IL; n = 3-5), other intermediate leaves (OIL; n = 5), blades of adult leaves (BAL; n = 4-5) and sheaths of adult leaves (SAL; n = 3-5). Concentrations are expressed as mean ± standard deviation in µg.g⁻¹_{DW}. *, **, struck-through values and nd represent concentrations < L_Q, < L_D, < L_C and not detected, respectively. Number of replicates varies from 3 to 5, depending on site and compartment.

Annex C. *Posidonia oceanica* compartmentalization of Be, Al, V, Cr, Mn, Fe, Co and Ni (a–h) at 4 of the 18 sites. Concentrations are expressed as mean $\pm$ standard deviation in $\mu\text{g}\cdot\text{g}^{-1}\text{DW}$. X-labels indicate the different compartments: third intermediate leaves (3IL), other intermediate leaves (OIL), blades of adult leaves (BAL) and sheaths of adult leaves (SAL); *, **, struck-through compartments and nd represent concentrations $< L_Q$, $< L_D$, $< L_C$ and not detected, respectively. Number of replicates varies from 3 to 5, depending on site and compartment.

i

j

k

l

m

n

o

p

Annex C (Continued). *Posidonia oceanica* compartmentalization of Be, Al, V, Cr, Mn, Fe, Co and Ni (i-p) at 4 of the 18 sites. Concentrations are expressed as mean $\pm$ standard deviation in $\mu\text{g.g}^{-1}\text{DW}$. X-labels indicate the different compartments: third intermediate leaves (3IL), other intermediate leaves (OIL), blades of adult leaves (BAL) and sheaths of adult leaves (SAL); *, **, struck-through compartments and nd represent concentrations $< L_Q$, $< L_D$, $< L_C$ and not detected, respectively. Number of replicates varies from 3 to 5, depending on site and compartment.

q

r

s

Annex C (Continued). *Posidonia oceanica* compartmentalization of Sb, Pb and Bi (q-s) at 4 of the 18 sites. Concentrations are expressed as mean $\pm$ standard deviation in $\mu\text{g.g}^{-1}_{\text{DW}}$. X-labels indicate the different compartments: third intermediate leaves (3IL), other intermediate leaves (OIL), blades of adult leaves (BAL) and sheaths of adult leaves (SAL); *, **, struck-through compartments and nd represent concentrations $< L_Q$, $< L_D$, $< L_C$ and not detected, respectively. Number of replicates varies from 3 to 5, depending on site and compartment.

Annex D. Spatial variation of Be, Al, V, Cr, Mn, Fe, Co and Ni (a–h) concentrations in *Posidonia oceanica* shoots at the 18 sites: Ensues (1), La Vesse (2), Corbière (3), Plateau des Chèvres (4), Riou (5), Bénat (6), Giens (7), Cap Roux (8), St Raphaël (9), Antibes (10), Villefranche (11), Calvi (I), Aregno (II), St Florent (III), Taglio Isolaccio (IV), Bravone (V), Ajaccio Sud (VI) and Ajaccio Nord (VII). X-axis labels indicate the sites along the coasts (1–11: PACA; I–VII: Corsica). Concentrations are expressed as mean $\pm$ standard deviation in $\mu\text{g}\cdot\text{g}^{-1}\text{DW}$.

Annex D (Continued). Spatial variation of Cu, Zn, As, Se, Mo, Ag, Cd and Sn (BAL) (i-p) concentrations in *Posidonia oceanica* shoots at the 18 sites: Ensues (1), La Vesse (2), Corbière (3), Plateau des Chèvres (4), Riou (5), Bénat (6), Giens (7), Cap Roux (8), St Raphaël (9), Antibes (10), Villefranche (11), Calvi (I), Aregno (II), St Florent (III), Taglio Isolaccio (IV), Bravone (V), Ajaccio Sud (VI) and Ajaccio Nord (VII). X-axis labels indicate the sites along the coasts (1–11: PACA; I–VII: Corsica). Concentrations are expressed as mean $\pm$ standard deviation in $\mu\text{g.g}^{-1}\text{DW}$.

Annex D (Continued). Spatial variation of Sb, Pb and Bi (q–s) concentrations in *Posidonia oceanica* shoots at the 18 sites: Ensues (1), La Vesse (2), Corbière (3), Plateau des Chèvres (4), Riou (5), Bénat (6), Giens (7), Cap Roux (8), St Raphaël (9), Antibes (10), Villefranche (11), Calvi (I), Aregno (II), St Florent (III), Taglio Isolaccio (IV), Bravone (V), Ajaccio Sud (VI) and Ajaccio Nord (VII). X-axis labels indicate the sites along the coasts (1–11: PACA; I–VII: Corsica). Concentrations are expressed as mean $\pm$ standard deviation in $\mu\text{g}\cdot\text{g}^{-1}_{\text{DW}}$.