

Metal bioaccumulation and oxidative stress in *Ulva laetevirens* in the Venice Lagoon: Early-warning biomarker for metal bioaccumulation

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Supplementary materials

Table S1. Physico-chemical parameters and nutrient concentrations for water, sediment, and SPM of VL sampling sites;(SMM: Santa Maria del Mare; PM: Porto Marghera; SG: San Giuliano)

matrix	Parameter	SMM	PM	SG
Water	pH	8.30±0.14	8.15±0.13	8.22±0.36
	Eh (mV)	103±25.6	101±41.8	178±149
	Sal (psu)	26.6±4.37	24.7±2.05	19.2±9.57
	Temp. (°C)	19.7±4.53	23.0±6.45	22.3±7.04
Sediment	pH	8.1±0.07	7.4±0.01	7.9±0.02
	Eh (mV)	168±1.4	-193±1.3	-80±1.5
	% Fines	21.4 ± 0.2	74.8 ± 0.3	93.0 ± 0.2
	% TOM	1.54 ± 0.12	4.57 ± 0.22	6.57 ± 0.38
	TN (mg/g)	0.10 ± 0.02	0.80 ± 0.08	1.40 ± 0.09
	Pinorg. (µg/g)	229 ± 4	463 ± 8	382 ± 4
	P org. (µg/g)	33.2 ± 2.2	11.4 ± 1.1	89.5 ± 3.4
SPM	% Fines	35.4 ± 0.3	70.0 ± 0.4	99.4 ± 0.6
	% TOM	3.52 ± 0.18	6.10 ± 0.11	6.92 ± 0.12
	TN (mg/g)	1.0 ± 0.04	1.6 ± 0.08	2.3 ± 0.10
	Pinorg. (µg/g)	281 ± 3	493 ± 9	606 ± 6.4
	P org. (µg/g)	81 ± 1.8	91 ± 3.4	217 ± 4.1

Legend: % Fines = percentage of fine fraction, % TOM = percentage of total organic matter, TN = total nitrogen, P inorg. = inorganic phosphorus, P org. = organic phosphorus, SPM = Settled Particulate Matter, Sal = salinity, Temp = Temperature.

Table S2a: Spearman correlation matrix of metals in sediment and SPM

	As sed	V sed	Ni sed	Mn sed	Zn sed	Cu sed	Pb sed	Hg sed
As sed								
V sed	n.s.							
Ni sed	n.s.	0.89						
Mn sed	n.s.	n.s.	n.s.					
Zn sed	0.89	n.s.	n.s.	n.s.				
Cu sed	0.94	n.s.	n.s.	n.s.	0.94			
Pb sed	n.s.	0.83	0.94	n.s.	n.s.	n.s.		
Hg sed	n.s.	0.93	0.87	n.s.	n.s.	n.s.	0.93	
As SPM	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
V SPM	n.s.	0.83	0.94	n.s.	n.s.	n.s.	1.00	0.93
Ni SPM	0.89	n.s.	n.s.	n.s.	1.00	0.94	n.s.	n.s.
Mn SPM	0.89	n.s.	n.s.	n.s.	1.00	0.94	n.s.	n.s.
Zn SPM	n.s.	1.00	0.89	n.s.	n.s.	n.s.	0.83	0.93
Cu SPM	n.s.	n.s.	n.s.	n.s.	0.81	n.s.	n.s.	n.s.
Pb SPM	n.s.	0.94	0.94	n.s.	n.s.	n.s.	0.89	0.93
Hg SPM	n.s.	0.94	0.94	n.s.	n.s.	n.s.	0.89	0.87

Legenda: n.s. (not significant); sed (sediment); SPM (suspended particulate matter); ULV (*U. laetevirens*). Significant scores with p<0.05.

Table S2b: Spearman correlation matrix of metals in sediment and SPM

	As SPM	V SPM	Ni SPM	Mn SPM	Zn SPM	Cu SPM	Pb SPM
As sed							
V sed							
Ni sed							
Mn sed							
Zn sed							
Cu sed							
Pb sed							
Hg sed							
As SPM							
V SPM	n.s.						
Ni SPM	n.s.	n.s.					
Mn SPM	n.s.	n.s.	1.00				
Zn SPM	n.s.	0.83	n.s.	n.s.			
Cu SPM	n.s.	n.s.	0.81	0.81	n.s.		
Pb SPM	n.s.	0.89	n.s.	n.s.	0.94	n.s.	
Hg SPM	n.s.	0.89	n.s.	n.s.	0.94	n.s.	0.89

Legend: n.s. (not significant); sed (sediment); SPM (suspended particulate matter); ULV (*U. laetevirens*). Significant scores with p<0.05.

Table S3: metals concentration in *Ulva* tissues within sampling seasons (µg/g dw) at LV. (SMM: Santa Maria del Mare; PM: Porto Marghera; SG: San Giuliano)

site	season	As	V	Ni	Mn	Zn	Cu	Pb	Hg
SMM	Winter	0.95	2.20	1.19	18.6	5.74	9.74	0.34	0.08
	Spring	2.49	0.73	2.49	29.5	15.9	4.51	0.06	0.14
	Summer	1.79	13.8	2.53	36.8	29.9	10.1	0.04	0.15
	Autumn	1.23	23.4	3.51	67.2	7.33	10.2	0.60	0.14
PM	Winter	6.51	1.19	2.06	47.9	18.8	5.65	0.49	0.21
	Spring	14.6	3.82	0.97	22.1	58.7	16.7	1.33	0.24
	Summer	11.1	4.17	1.44	30.9	48.1	73.7	0.17	0.21
	Autumn	7.51	0.05	1.09	24.5	7.47	19.1	0.48	0.24
SG	Winter	3.53	0.79	2.93	89.2	38.5	11.5	1.34	0.28
	Spring	4.31	1.07	2.73	400	93.5	52.1	4.23	0.33
	Summer	4.88	3.82	1.13	117	76.7	43.9	3.34	0.22
	Autumn	6.40	0.23	0.97	52.1	16.1	9.37	1.85	0.21
Average		As	V	Ni	Mn	Zn	Cu	Pb	Hg
SMM		1.62	10.0	2.43	38.0	14.7	8.63	0.26	0.13
PM		9.93	2.30	1.39	31.3	33.3	28.8	0.62	0.23
SG		4.78	1.48	1.94	165	56.2	29.2	2.69	0.26

Table S4: LPO (lipid peroxidation) seasonal measurement at LV sites (SMM: Santa Maria del Mare; PM: Porto Marghera; SG: San Giuliano)

Site	LPO (µM/g)					
	Winter	Spring	Summer	Autumn	Avg.	St. Dev.
SMM	7.46	4.82	5.17	14.1	7.89	4.30
PM	19.7	32.0	24.2	26.8	25.7	5.10
SG	31.8	55.3	15.4	28.7	32.8	16.6

Table S5: Spearman correlation matrix of metals in *U. laetevirens* and oxidative stress damage (LPO)

	As ULV	V ULV	Ni ULV	Mn ULV	Zn ULV	Cu ULV	Pb ULV	Hg ULV	MPI
As ULV									
V ULV	n.s.								
Ni ULV	-0.59	n.s.							
Mn ULV	n.s.	n.s.	n.s.						
Zn ULV	n.s.	n.s.	n.s.	n.s.					
Cu ULV	n.s.	n.s.	n.s.	n.s.	0.62				
Pb ULV	n.s.	n.s.	n.s.	0.68	n.s.	n.s.			
Hg ULV	n.s.	n.s.	n.s.	n.s.	0.73	0.59	0.66		
MPI	n.s.	n.s.	n.s.	0.61	0.87	0.63	0.60	n.s.	
LPO	0.60	n.s.	n.s.	n.s.	n.s.	n.s.	0.71	0.88	n.s.

Legend: n.s. (not significant); MPI (metal pollution index); ULV (*U. laetevirens*); LPO (Lipid peroxidation).