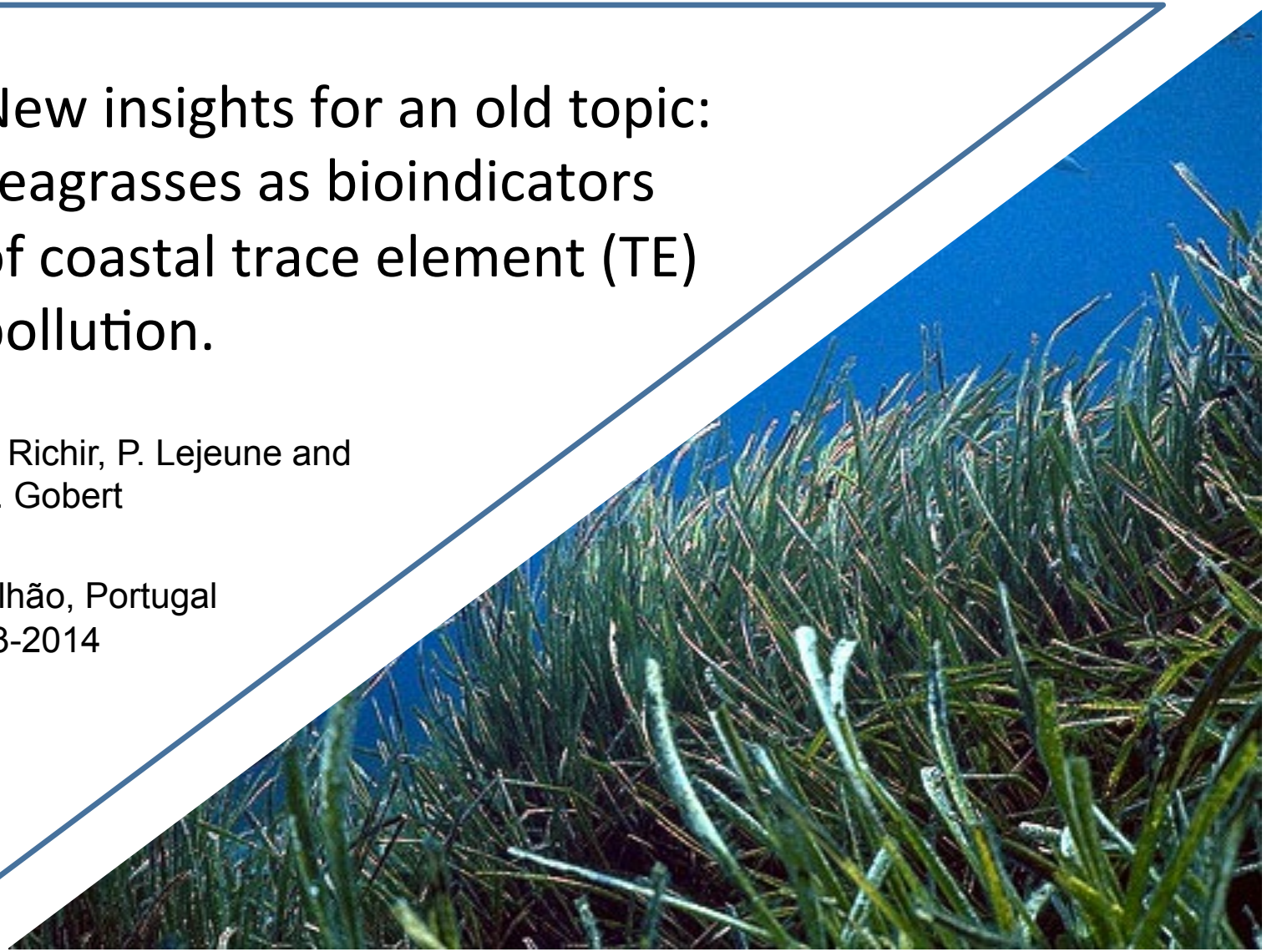
New insights for an old topic: seagrasses as bioindicators of coastal trace element (TE) pollution.

J. Richir, P. Lejeune and S. Gobert

Olhão, Portugal
03-2014



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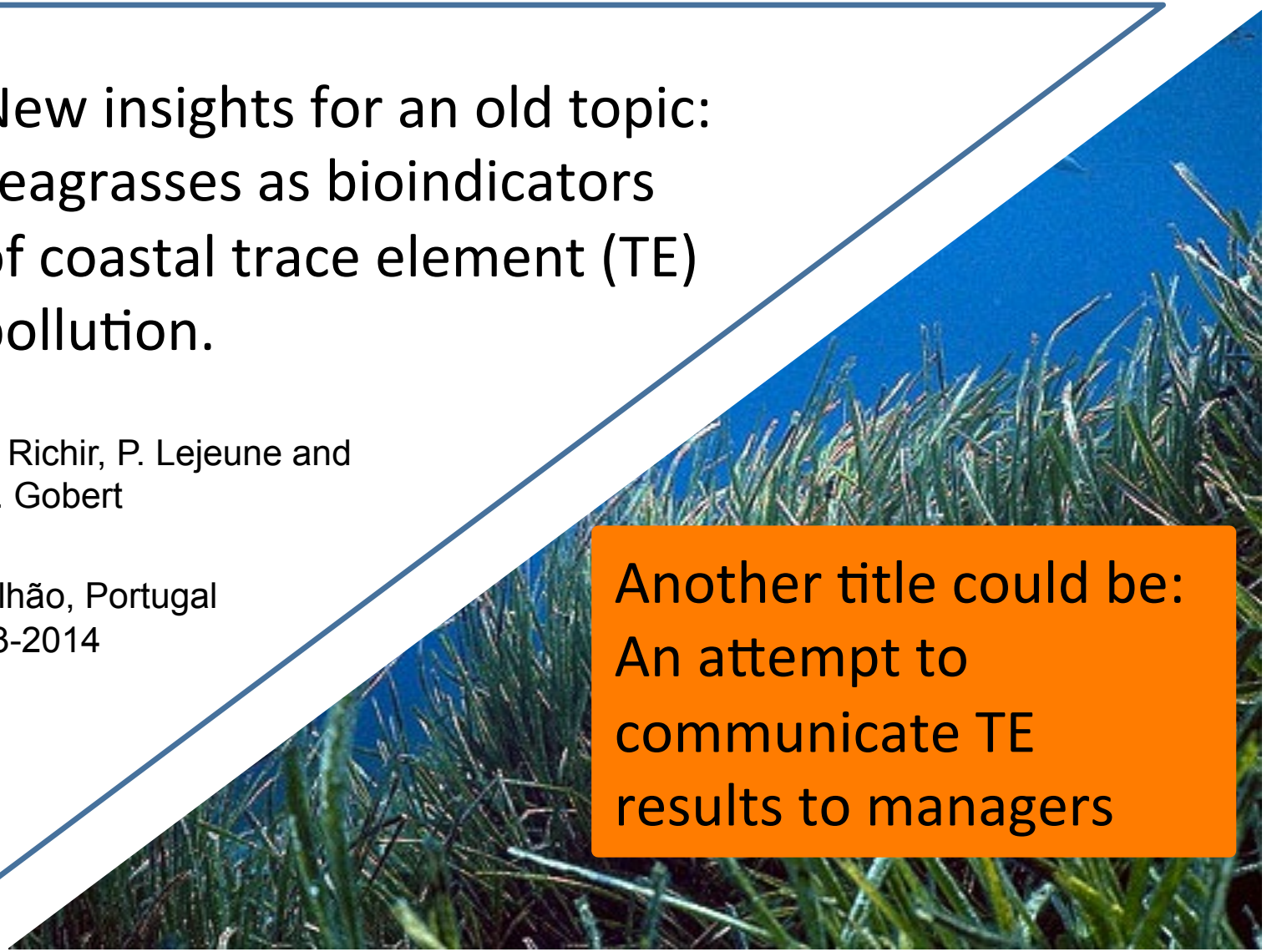

Another title could be: An attempt to communicate TE results to managers

Pollution by TE is still a topical subject

World production of 19 trace elements

TE	Symbol	Year				
		1990	2000	↗(1990)	2010	↗(1990)
Aluminum	Al	17.817	24.400	37%	40.800	129%
Antimony	Sb	83,2	122,0	47%	167,0	101%
Arsenic	As	47,6	36,9	-23%	52,8	11%
Beryllium	Be	0,286	0,226	-21%	0,203	-29%
Bismuth	Bi	3,333	3,752	13%	8,467	154%
Cadmium	Cd	20,16	20,23	0%	21,40	6%
Chromium	Cr	12.846	4.320	-66%	7.290	-43%
Cobalt	Co	37,1	33,3	-10%	89,5	141%
Copper	Cu	8.815	13.200	50%	16.000	82%
Iron	Fe	543.000	1.061.148	95%	2.590.000	377%
Lead	Pb	3.367	3.100	-8%	4.140	23%
Manganese	Mn	27,2	20,2	-26%	42,7	57%
Molybdenum	Mo	112	129	16%	242	117%
Nickel	Ni	1.029	1.250	21%	1.590	54%
Selenium	Se	1.789	1.460	-18%	2.120	19%
Silver	Ag	17,7	18,4	4%	23,1	31%
Tin	Sn	219	238	9%	265	21%
Vanadium	V	31,0	43,0	39%	57,6	86%
Zinc	Zn	7.325	8.730	19%	12.000	64%

After suffering a slight slowdown at the end of the 90s.

compiled from the Mineral Yearbooks published by the US Geological Survey website, http://www.usgs.gov/

Monitoring of TE: a topical subject

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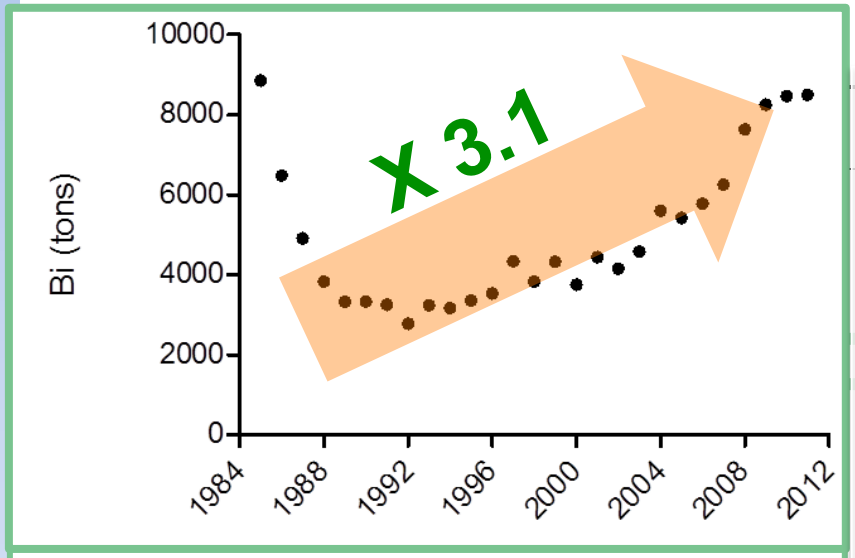
Zinc	Zn	7.325	8.730	19%	12.000	64%

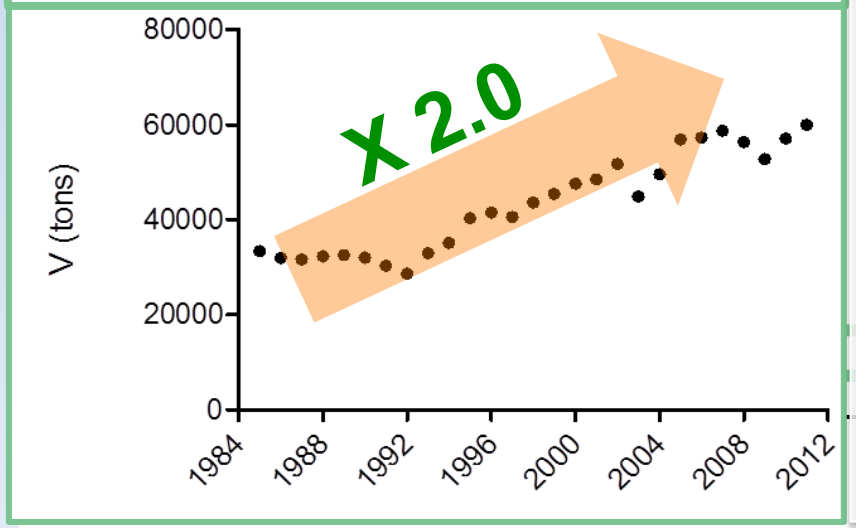
After suffering a slight slowdown at the end of the 90s.

Experiencing new growth as a result of the emergence of all a series of nations

compiled from the Mineral Yearbooks published by the US Geological Survey website, http://www.usgs.gov/

Monitoring of TE: a topical subject





metallurgical additives, electronic and thermoelectric applications.
for catalysts, pearlescent pigments in cosmetics, pharmaceuticals, and industrial chemicals

from train rails, tool steels, catalysts, to aerospace…

compiled from the Mineral Yearbooks published by the US Geological Survey website, http://www.usgs.gov/

P.o. is well known as a TE bioindicator

organism accumulating pollutants to levels representative of their habitat pollution status

Monitoring of TE: a topical subject

Number of references (1975-2012) on trace elements studied in Posidonia oceanica

TE	Cd	Pb	Cu	Zn	Cr	Fe	Ni
# ref.	34	29	27	25	22	14	13

TE	As	Se	Ag	Co	Mn	Al
# ref.	3	3	2	2	2	1
TE	**Be**	**Bi**	**V**	**Mo**	**Sn**	**Sb**
# ref.	0	0	0	0	0	0

"Classical"

widely used since the mid-70th : Cr, Ni, Cu, Zn, Cd, Pb and/or Fe.

Luy et al. (2012; Ecological Indicators)

Monitoring of TE: a topical subject

Number of references (1975-2012) on trace elements studied in Posidonia oceanica

TE	Cd	Pb	Cu	Zn	Cr	Fe	Ni
# ref.	34	29	27	25	22	14	13

TE	As	Se	Ag	Co	Mn	Al
# ref.	3	3	2	2	2	1
TE	**Be**	**Bi**	**V**	**Mo**	**Sn**	**Sb**
# ref.	0	0	0	0	0	0

"emerging concern"

widely used since the mid-70th : Cr, Ni, Cu, Zn, Cd, Pb and/or Fe.

As, V, Ag, Be, Al, Mn, Co, Se, Mo, Sn, Sb and Bi have been subject to nearly no ecotoxicological survey

Luy et al. (2012; Ecological Indicators)

Since some years, we monitor

P. oceanica

Objectives

19 TEs
(Cr, Ni, Cu, Zn, Cd, Pb, As, Ag, V, Be, Al, Fe, Mn, Co, Se, Mo, Sn, Sb and Bi).
along the French coasts of the Mediterranean Sea

Data:

Different spatial scales
April 2007: 18 sites along French coats (PACA and Corsica)
May 2010: 9 stations along a 3 km transect in Ajaccio Bay
June 2010: 4 stations remote from 1-3 km in Calvi Bay
+
Temporal scales (seasonnal, interannual)
March, June, November 2008, 2009, 2010
+
Specific compartment instead of entire organisms

+
M galloprovincialis

Ecological Indicators 36 (2014) 33–47

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Original article

The effect of size, weight, body compartment, sex and reproductive status on the bioaccumulation of 19 trace elements in rope-grown *Mytilus galloprovincialis*

J. Richir*, S. Gobert

Aquatic Toxicology 140–141 (2013) 157–173

Contents lists available at SciVerse ScienceDirect

Aquatic Toxicology

As we would like to define "A mean to communicate TE results to managers"..

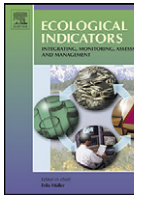
Experimental *in situ* exposure of the seagrass *Posidonia oceanica* (L.) Delile to 15 trace elements

J. Richir[a,*], N. Luy[a], G. Lepoint[a], E. Rozet[b], A. Alvera Azcarate[c], S. Gobert[a]

Contents lists available at SciVerse ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind



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

Nicolas Luy[a,*], Sylvie Gobert[a], Stéphane Sartoretto[b], Renzo Biondo[a], Jean-Marie Bouquegneau[a], Jonathan Richir[a]

P. oceanica

trace element pollution ➡ Mediterranean

Evaluation of the effect of data pre-treatment procedures on classical pattern recognition and principal components analysis: a case study for the geographical classification of tea

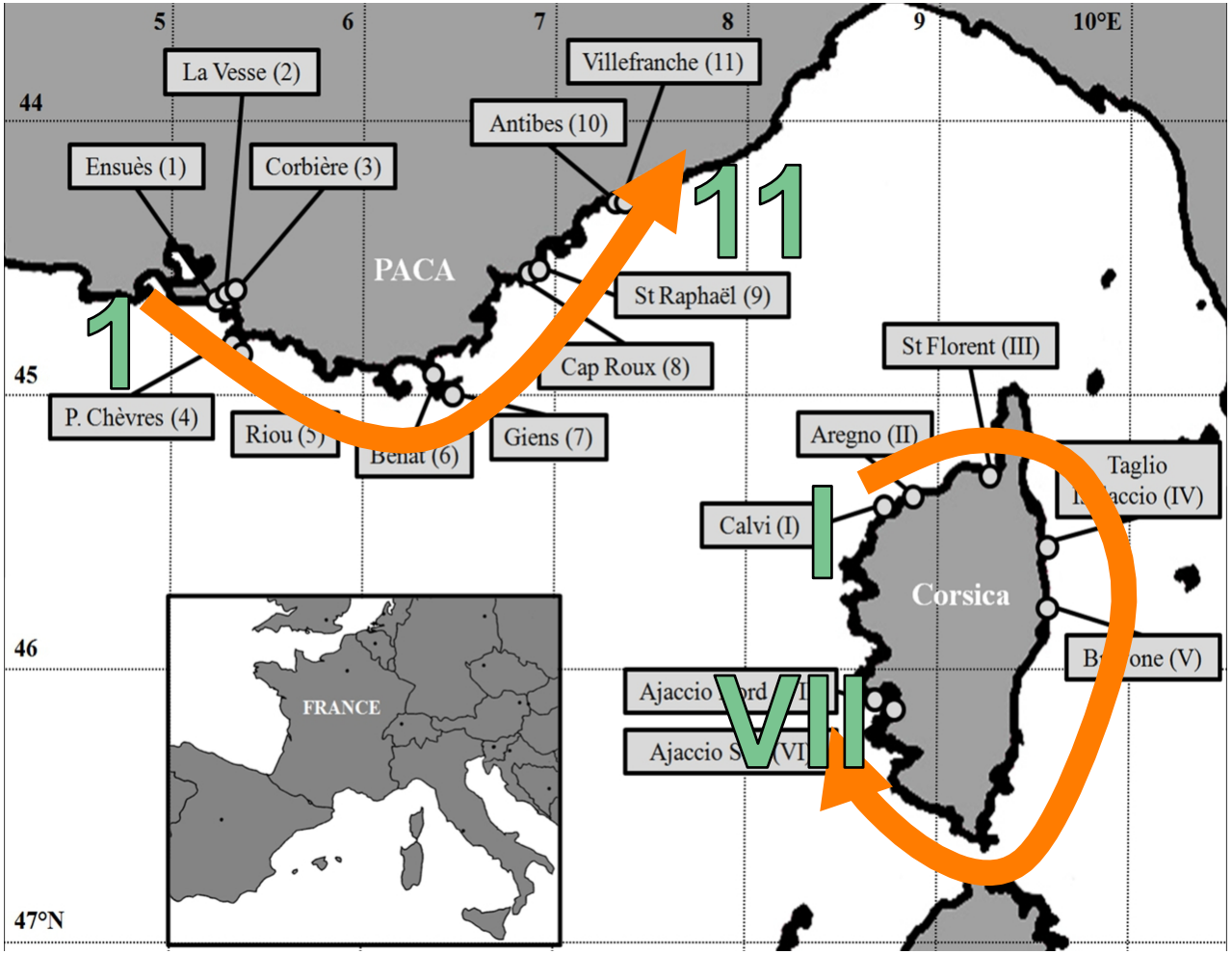
Antonio Moreda-Piñeiro,[a] Ana Marcos,[b] Andrew Fisher[b] and Steve J. Hill*[b]

Two indices

(i) the TESVI (Trace Element Spatial Variation Index), to give a general overview of the TEs spatial variability through a studied area

(ii) the TEPI (Trace Element Pollution Index), a weighted version of the metal pollution index MPI (Usero et al. 1996) allowing the reliable comparison of global pollution levels in TEs between several monitored sites

- *P. oceanica* sampled in 18 sites at 15 m depth
- 19 TEs analysed (Be, Al, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sn, Sb, Pb, Bi)
- Anthropgenic activities



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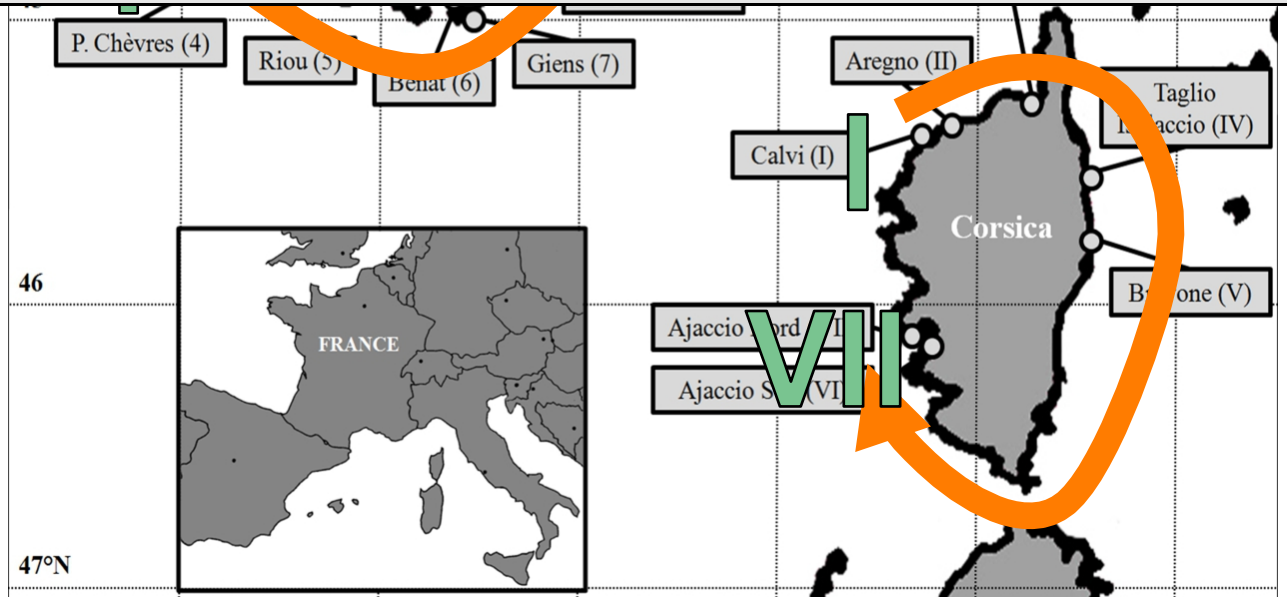
- Anthropgenic activities

Results

Impact factors	Criteria
Fish farming	Number, production
Industrial development	Type, zoning
Agriculture	Exploited surface, type of exploitation
Tourism	Number of camping, marina, beach and second home; tourism fluxes (airport, ferries…)
Fishing	Fishing, fleetfishing port, employment, type of activity (artisanal, deep-sea…)
Commercial port	Harbour traffic, type of activities
Urbanization	Sewer, population density



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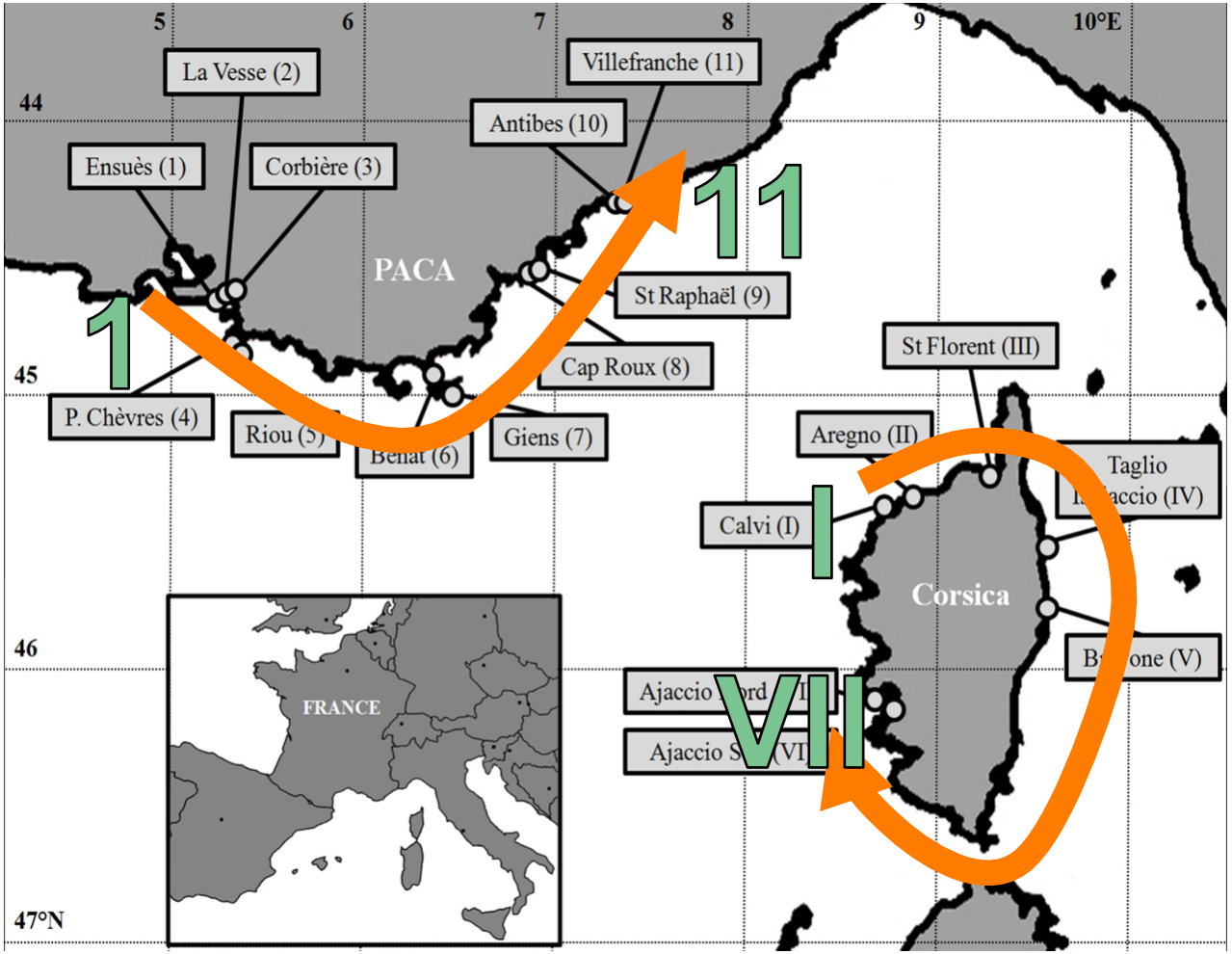
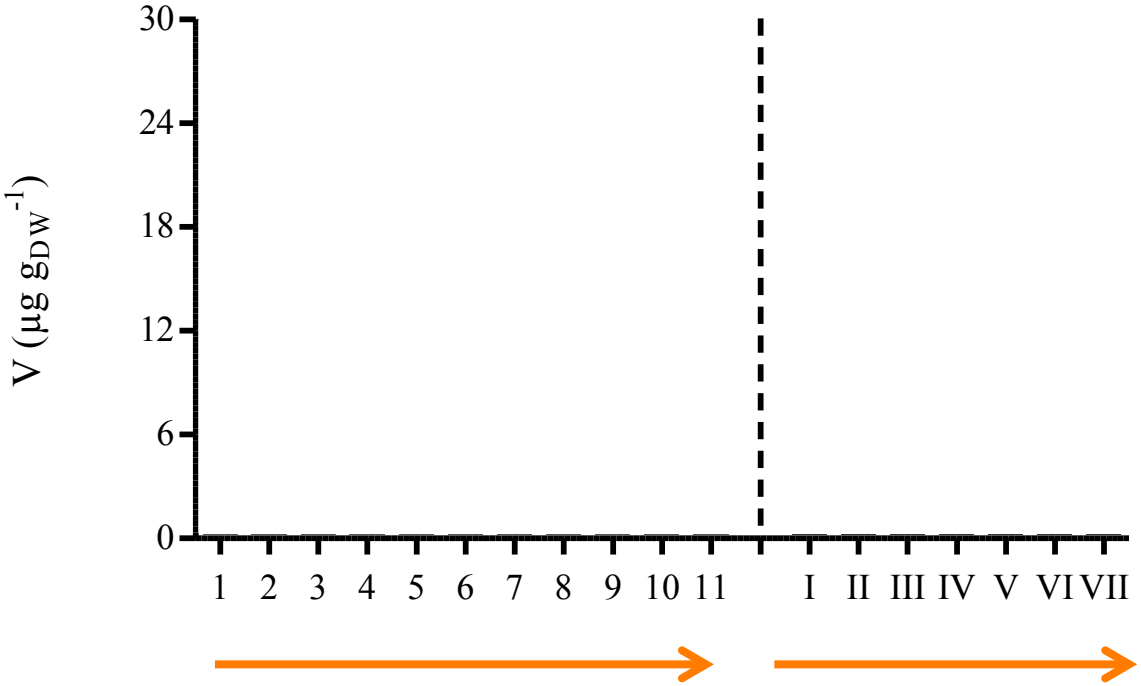
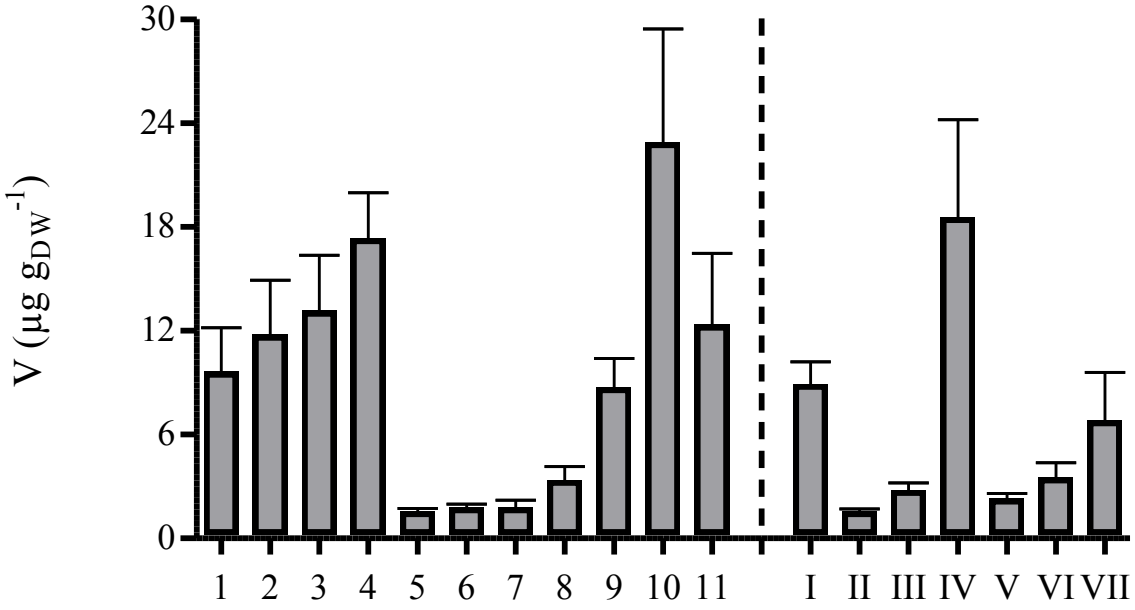


e.g. 1 - Vanadium pollution



V is a tracer of oil spill (hydrocarbon) pollutants

e.g. 1 - V pollution



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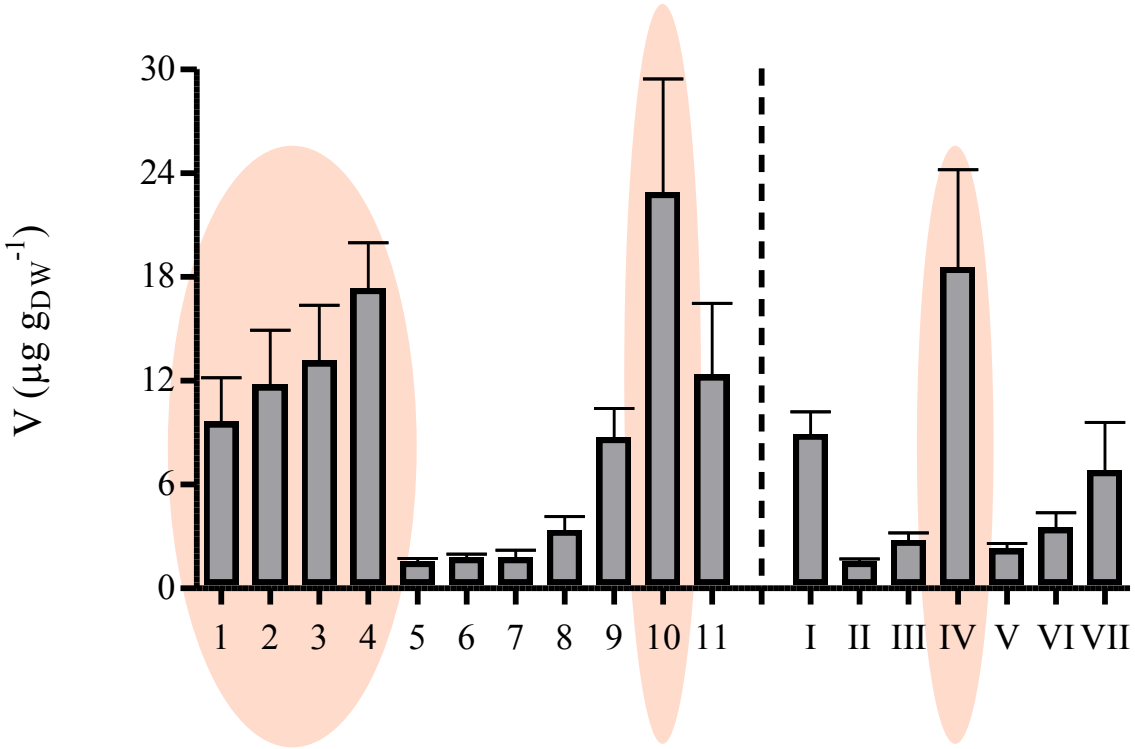
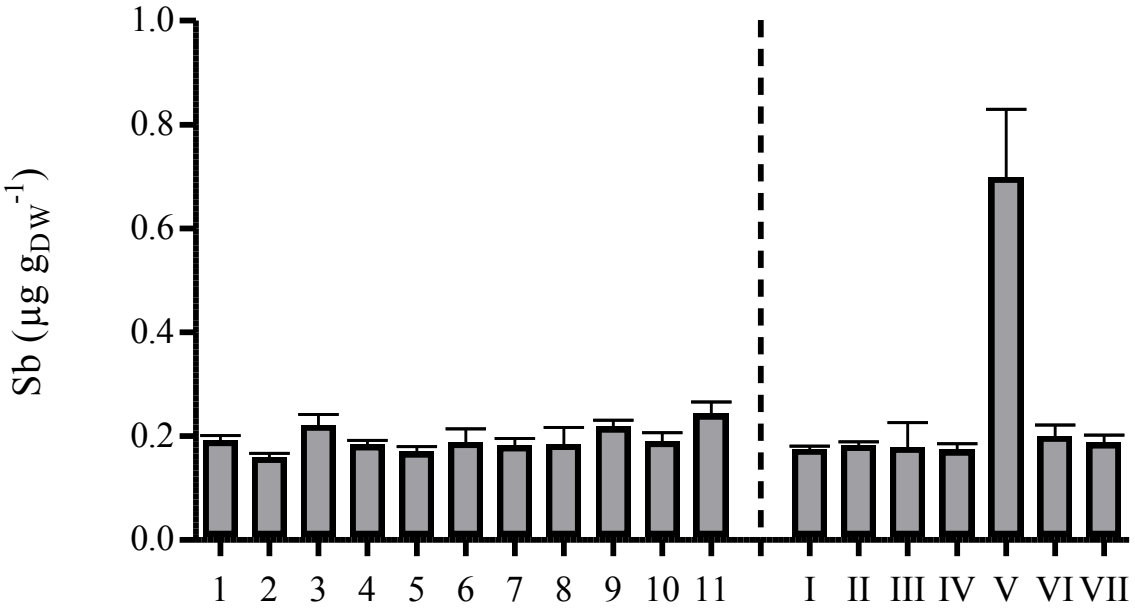


Marseille oil refinery

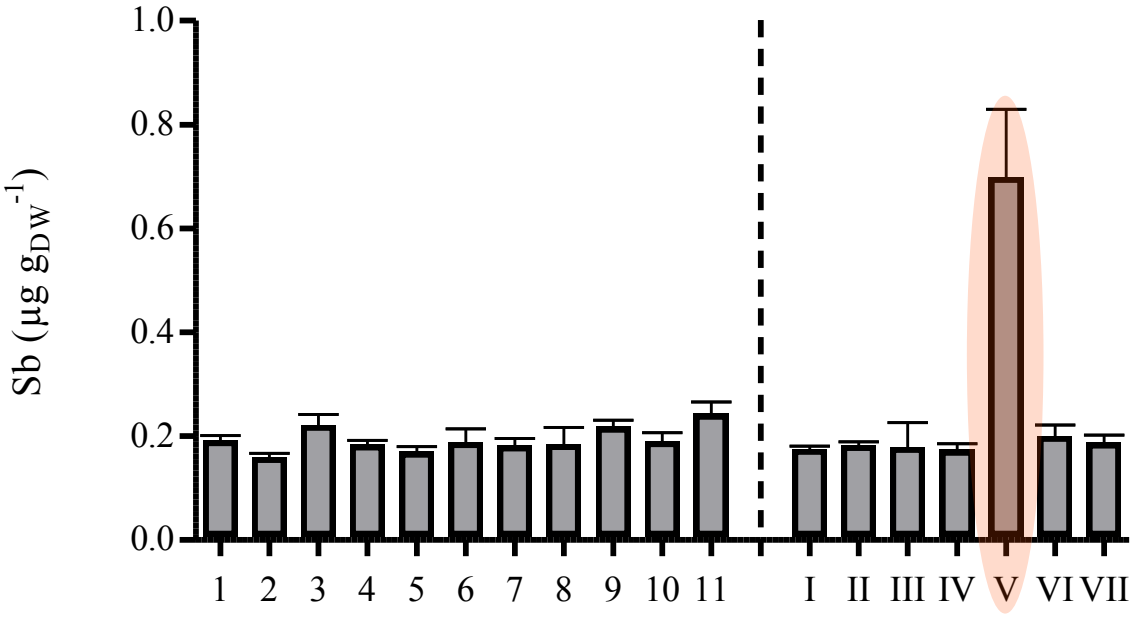
Antibes oil-exporting harbour

Taglio-Isolaccio petroleum depot

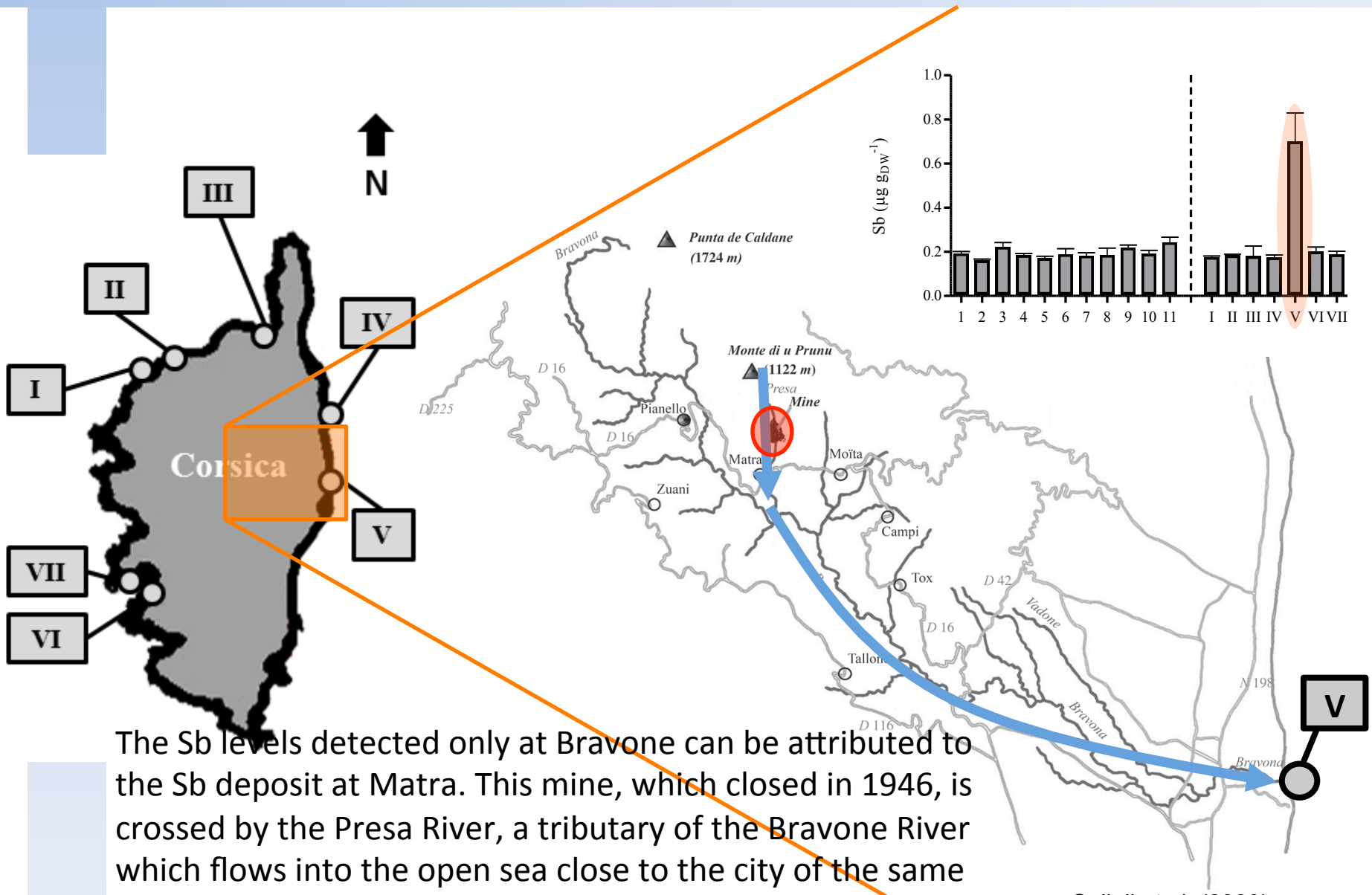
e.g. 1 - Sb pollution



e.g. 1 - Sb pollution



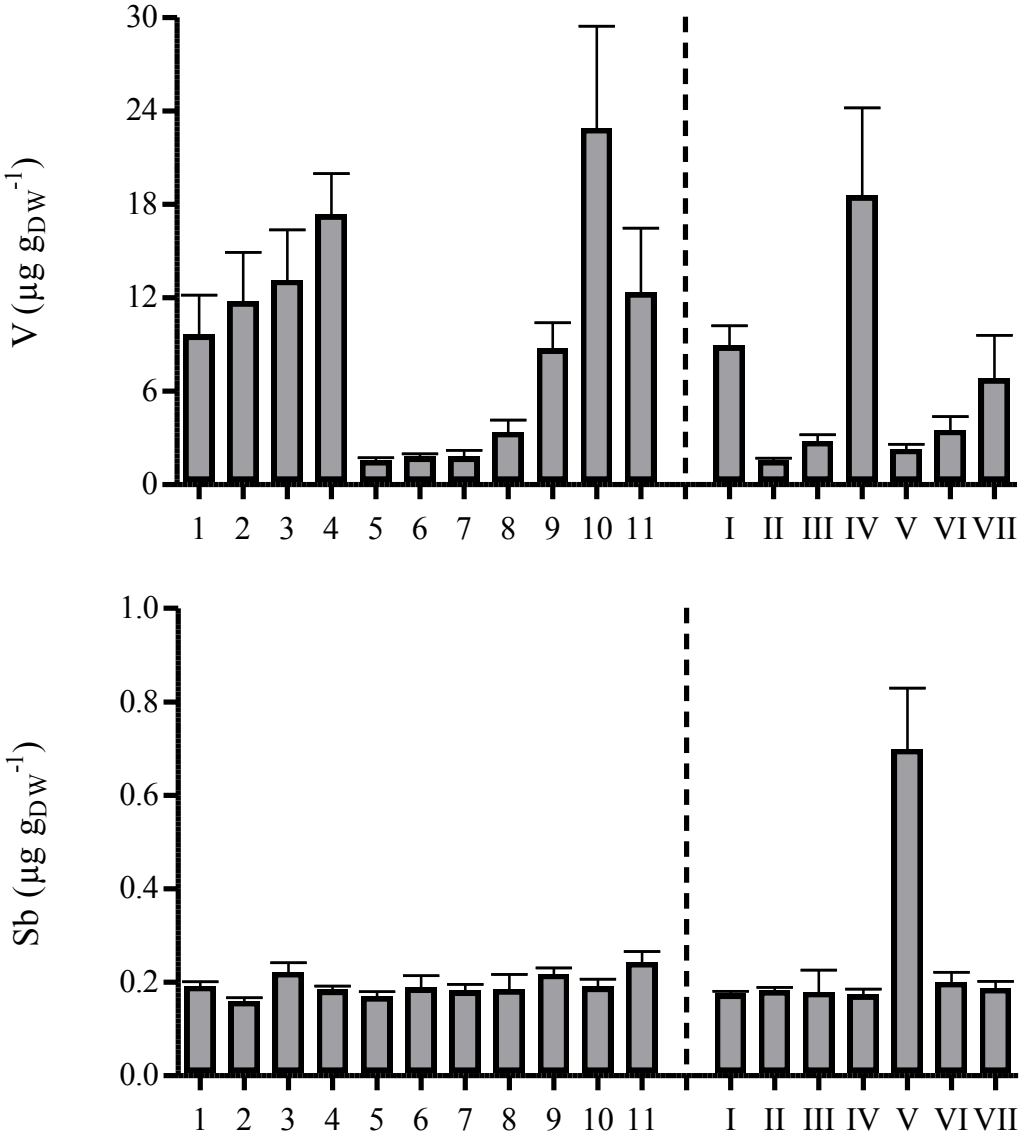
e.g. 1 - Antimony pollution

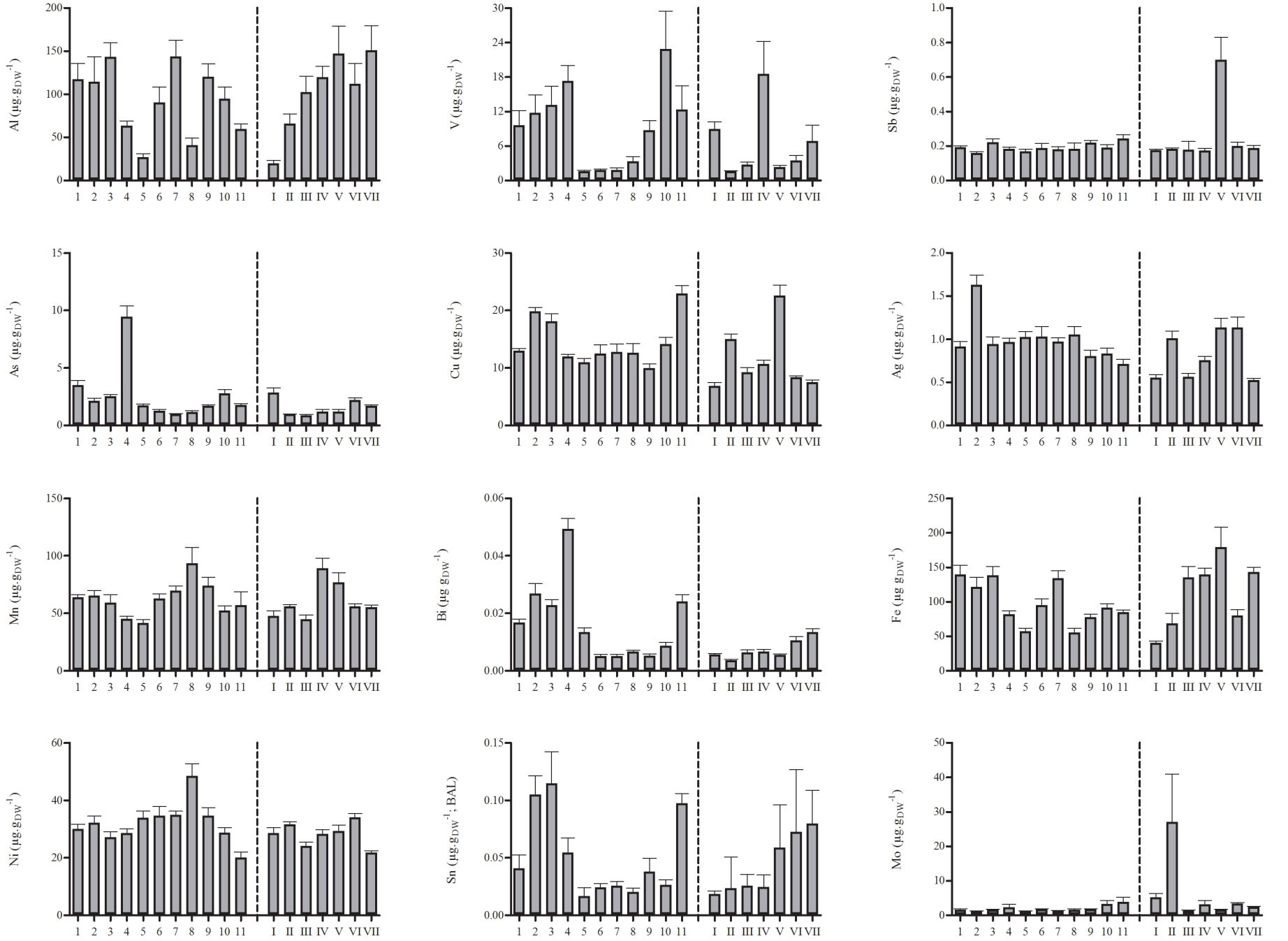


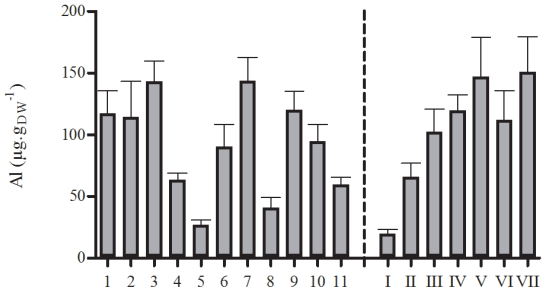
The Sb levels detected only at Bravone can be attributed to the Sb deposit at Matra. This mine, which closed in 1946, is crossed by the Presa River, a tributary of the Bravone River which flows into the open sea close to the city of the same name (Bravone).

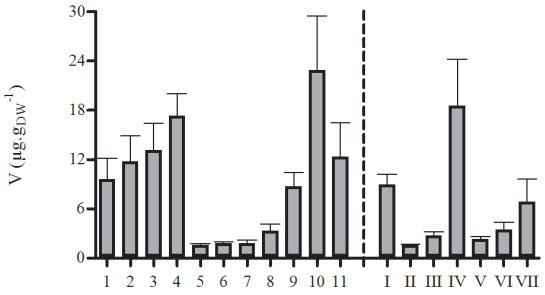
Culioli et al. (2009)

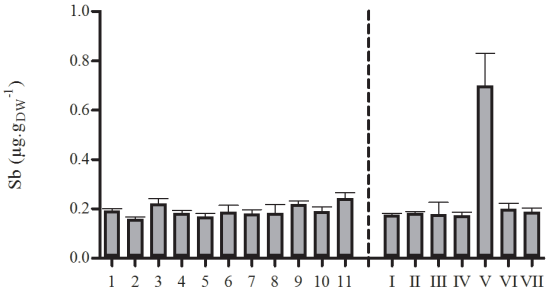
V vs. Sb


V (µg g$_{DW}^{-1}$)
30
24
18
12
6
0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII
Sb (µg g$_{DW}^{-1}$)
1.0
0.8
0.6
0.4
0.2
0.0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

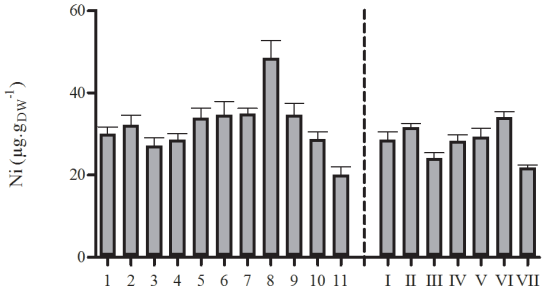

Al (µg·g$_{DW}^{-1}$)
V (µg·g$_{DW}^{-1}$)
Sb (µg·g$_{DW}^{-1}$)
As (µg·g$_{DW}^{-1}$)
Cu (µg·g$_{DW}^{-1}$)
Ag (µg·g$_{DW}^{-1}$)
Mn (µg·g$_{DW}^{-1}$)
Bi (µg g$_{DW}^{-1}$)
Fe (µg g$_{DW}^{-1}$)
Ni (µg·g$_{DW}^{-1}$)
Sn (µg·g$_{DW}^{-1}$; BAL)
Mo (µg·g$_{DW}^{-1}$)
1 2 3 4 5 6 7 8 9 10 11
I II III IV V VI VII

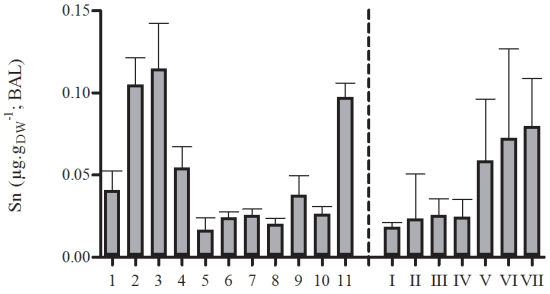


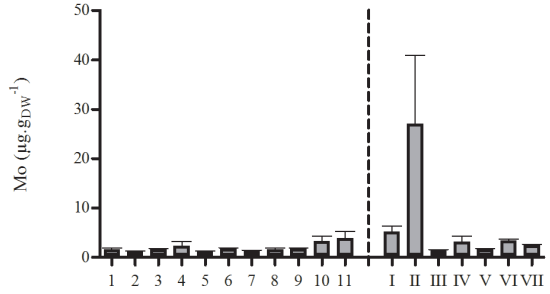




1. How to compare TEs according to the overall spatial variability ?





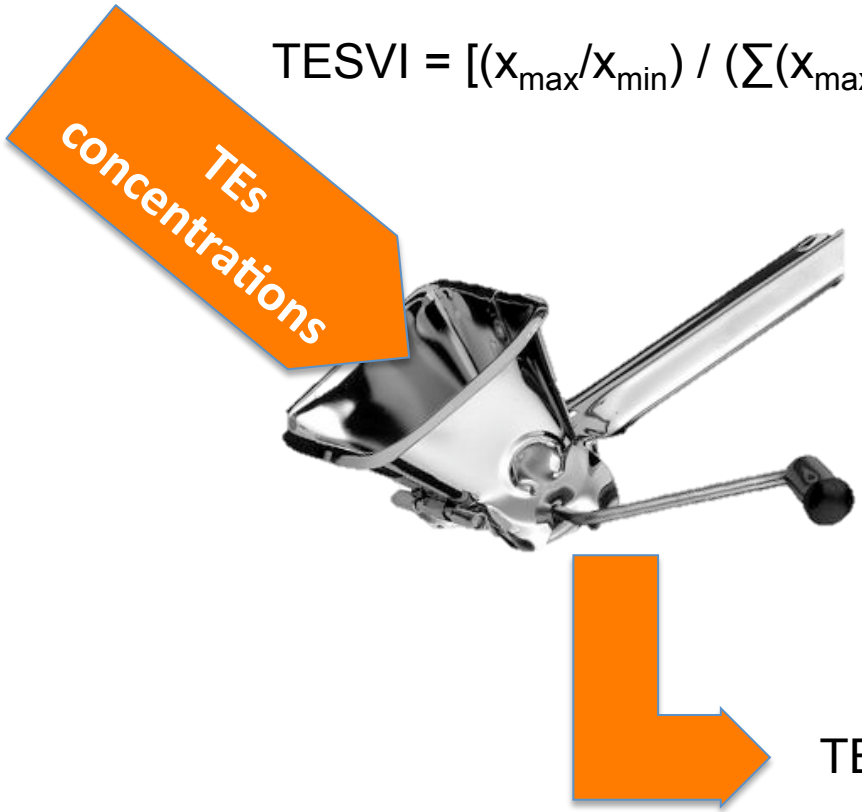


How to compare TEs according to the overall spatial variability?

TESVI

Trace Element Spatial Variation Index (TESVI)

$$TESVI = [(x_{max}/x_{min}) / (\sum(x_{max}/x_i)/n)] * SD$$



Trace Element Spatial Variation Index (TESVI)

$$TESVI = [(x_{max}/x_{min}) / (\sum(x_{max}/x_i)/n)] * SD$$

where:

- x_{max} and x_{min} are the maximum and minimum mean concentrations recorded among the n sites,
- x_i are mean concentrations recorded in each of the n sites,
- SD is the standard deviation of the weighted sum $\sum(x_{max}/x_i)/n$.

For one TE considered, a high the index value

The environmental levels of a TE have a high spatial variation on the studied area.

TESVI

Trace Element Spatial Variation Index (TESVI)

$$TESVI = [(x_{max}/x_{min}) / (\sum(x_{max}/x_i)/n)] * SD$$

where:

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For one TE, a high the index value

The environmental levels of a TE have a high spatial variation on the studied area.

Ring the alarm bells

TESVI

A. TEs broadly monitored with *P. oceanica*

	x_{max}/x_{min}	$\sum(x_{max}/x_i)/18 \pm SD$	TESVI
Cr	6.0	3.6 ± 1.3	2.2
Fe	4.4	2.0 ± 0.9	1.9
Ni	2.4	1.6 ± 0.3	0.5
Cu	3.4	1.9 ± 0.7	1.2
Zn	19.6	13.3 ± 4.4	6.5
Cd	3.9	1.9 ± 0.7	1.4
Pb	4.4	2.7 ± 1.2	2.0

B. TEs little monitored with *P. oceanica*

	x_{max}/x_{min}	$\sum(x_{max}/x_i)/18 \pm SD$	TESVI
Be	3.1	1.6 ± 0.6	1.0
Al	7.5	2.2 ± 1.8	6.1
V	14.5	5.9 ± 5.0	12.3
Mn	2.2	1.6 ± 0.4	0.5
Co	2.9	1.8 ± 0.5	0.7
As	10.6	5.9 ± 2.7	4.9
Se	1.7	1.3 ± 0.2	0.3
Mo	22.8	13.6 ± 6.2	10.5
Ag	3.1	1.9 ± 0.6	0.9
Sn (BA	6.9	3.5 ± 1.9	3.8
Sb	4.4	3.6 ± 0.7	0.9
Bi	13.6	6.1 ± 3.5	7.9

TESVI

A. TEs broadly monitored with *P. oceanica*

	x_{max}/x_{min}	$\sum(x_{max}/x_i)/18 \pm SD$	TESVI
Cr	6.0	3.6 ± 1.3	2.2
Fe	4.4	2.0 ± 0.9	1.9
Ni	2.4	1.6 ± 0.3	0.5
Cu	3.4	1.9 ± 0.7	1.2
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Cd	3.9	1.9 ± 0.7	1.4
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B. TEs little monitored with *P. oceanica*

	x_{max}/x_{min}	$\sum(x_{max}/x_i)/18 \pm SD$	TESVI
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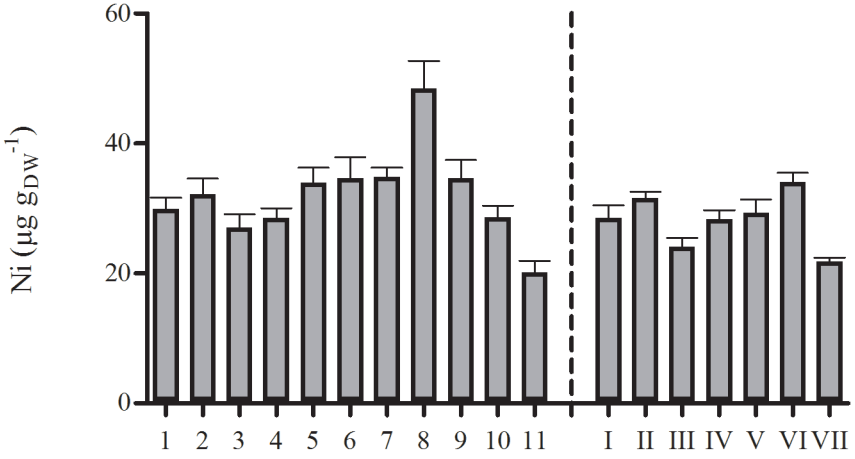
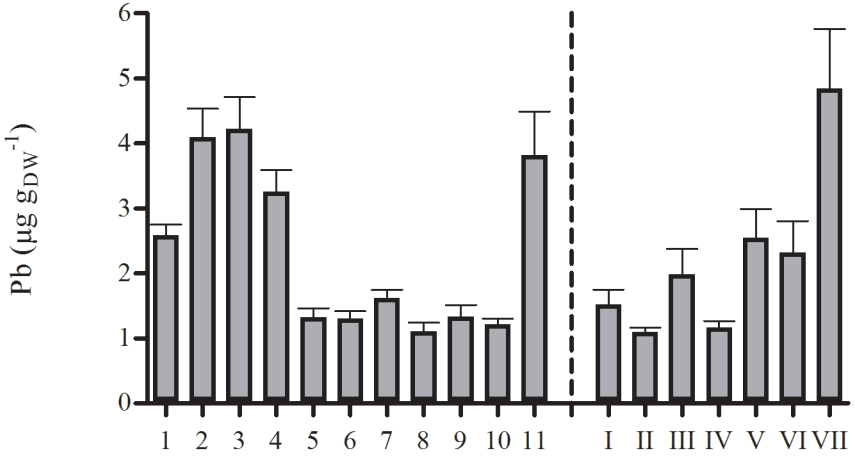
Al	7.5	2.2 ± 1.8	6.1
V	14.5	5.9 ± 5.0	12.3
Mn	2.2	1.6 ± 0.4	0.5
Co	2.9	1.8 ± 0.5	0.7
As	10.6	5.9 ± 2.7	4.9
Se	1.7	1.3 ± 0.2	0.3
Mo	22.8	13.6 ± 6.2	10.5
Ag	3.1	1.9 ± 0.6	0.9
Sn (BAL)	6.9	3.5 ± 1.9	3.8
Sb	4.4	3.6 ± 0.7	0.9
Bi	13.6	6.1 ± 3.5	7.9

TESVI values were listed in ascending order :
Se, Ni, Mn, Co, Sb, Ag, Be, Cu, Cd, Fe, Pb, Cr, Sn, As, Al, Zn, Bi, Mo, V

TESVI graphical representation





TESVI values were listed in ascending order :
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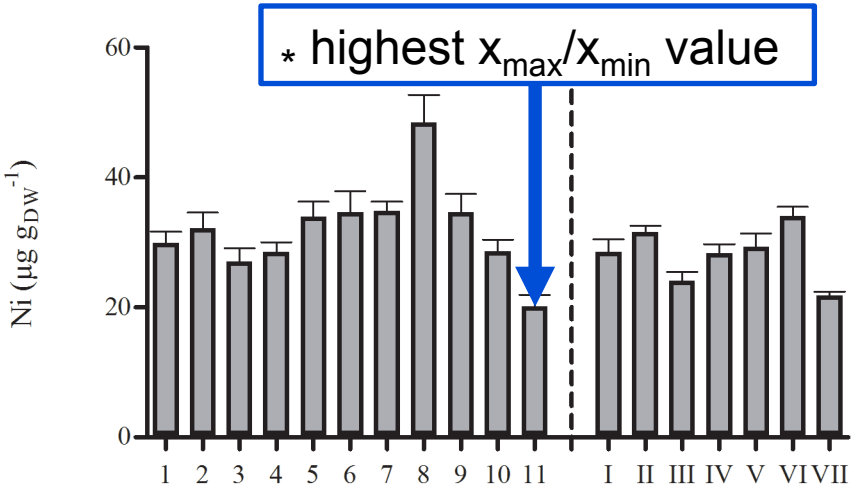
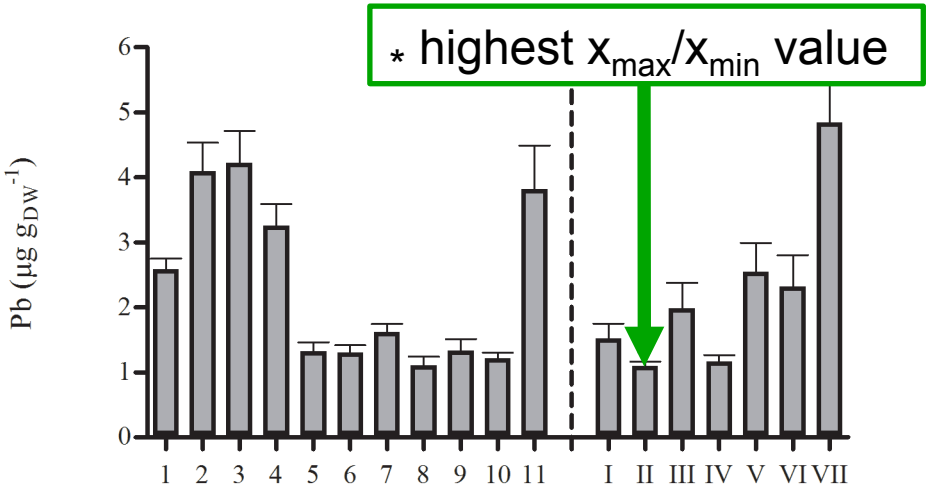
TESVI graphical representation





The graphical comparison of the overall spatial variability of trace element (TE) concentrations is based on the use of a proportional ordinate scaling between TEs, obtained by multiplying the minimum recorded mean concentration of each TE by the highest xmax/xmin mean concentration ratio (22.8 for Mo) calculated among the 19 studied TEs.

TESVI values were listed in ascending order :
Se, **Ni**, Mn, Co, Sb, Ag, Be, Cu, Cd, Fe, **Pb**, Cr, Sn, As, Al, Zn, Bi, Mo, V

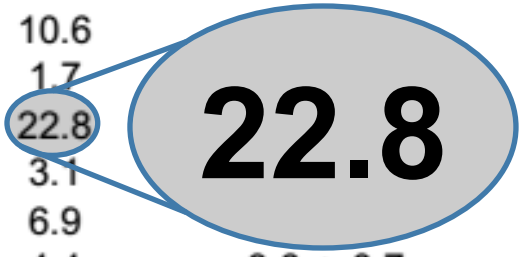
TESVI

A. TEs broadly monitored with *P. oceanica*

	x_{max}/x_{min}	$\sum(x_{max}/x_i)/18 \pm SD$	TESVI	Site x_{max}
Cr	6.0	3.6 ± 1.3	2.2	St Florent
Fe	4.4	2.0 ± 0.9	1.9	Bravone
Ni	2.4	1.6 ± 0.3	0.5	St Raphaël
Cu	3.4	1.9 ± 0.7	1.2	Villefranche
Zn	19.6	13.3 ± 4.4	6.5	Bravone
Cd	3.9	1.9 ± 0.7	1.4	St Raphaël
Pb	4.4	2.7 ± 1.2	2.0	Ajaccio N.

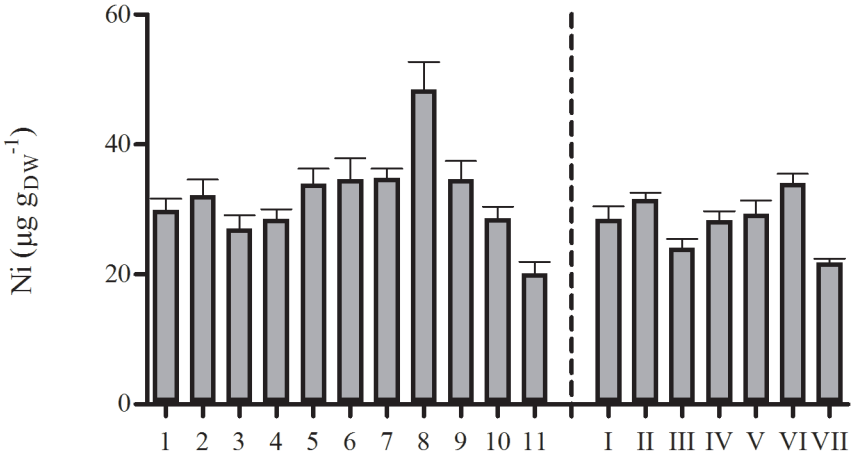
B. TEs little monitored with *P. oceanica*

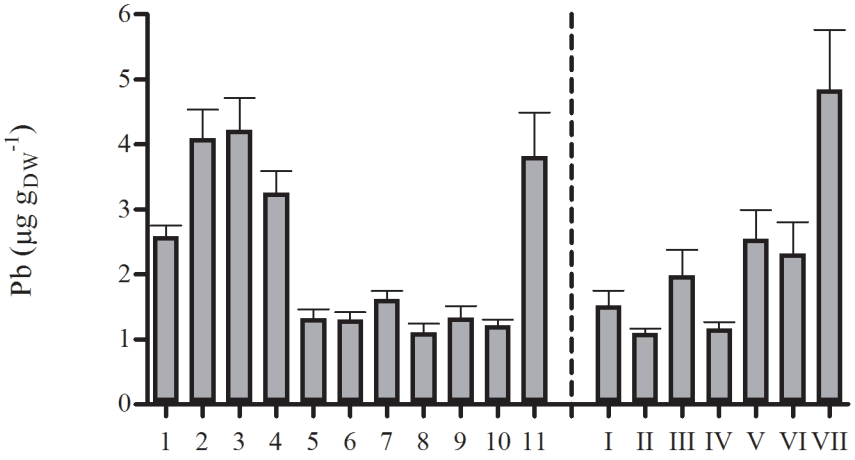
	x_{max}/x_{min}	$\sum(x_{max}/x_i)/18 \pm SD$	TESVI	Site x_{max}
Be	3.1	1.6 ± 0.6	1.0	Ajaccio N.
Al	7.5	2.2 ± 1.8	6.1	Ajaccio N.
V	14.5	5.9 ± 5.0	12.3	Antibes
Mn	2.2	1.6 ± 0.4	0.5	St Raphaël
Co	2.9	1.8 ± 0.5	0.7	St Raphaël
As	10.6		4.9	P. des Chèvres
Se	1.7		0.3	Calvi
Mo	22.8		10.5	Aregno
Ag	3.1		0.9	La Vesse
Sn (BAL)	6.9		3.8	Corbière
Sb	4.4	3.6 ± 0.7	0.9	Bravone
Bi	13.6	6.1 ± 3.5	7.9	P. des Chèvres



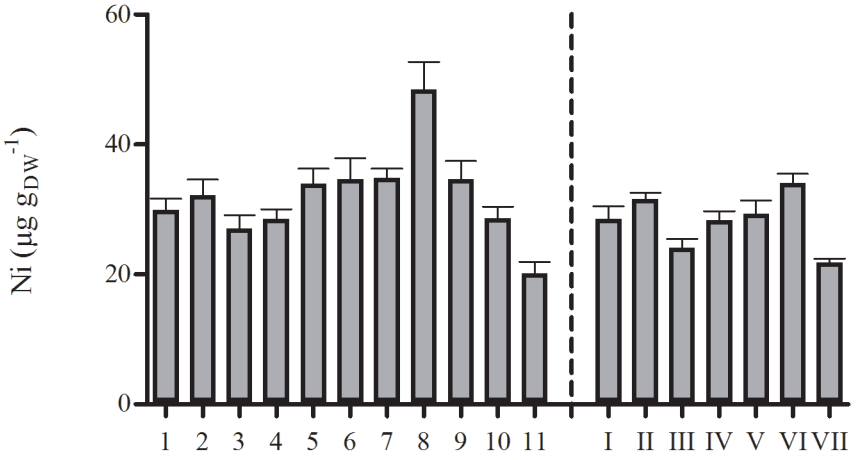
TESVI values were listed in ascending order :
Se, **Ni**, Mn, Co, Sb, Ag, Be, Cu, Cd, Fe, **Pb**, Cr, Sn, As, **Al**, Zn, Bi, Mo, **V**

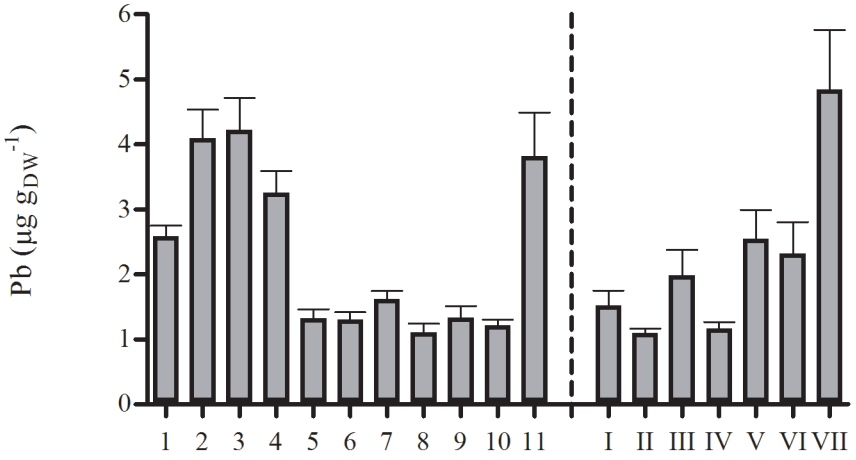
Classic graphical representation





Classic graphical representation

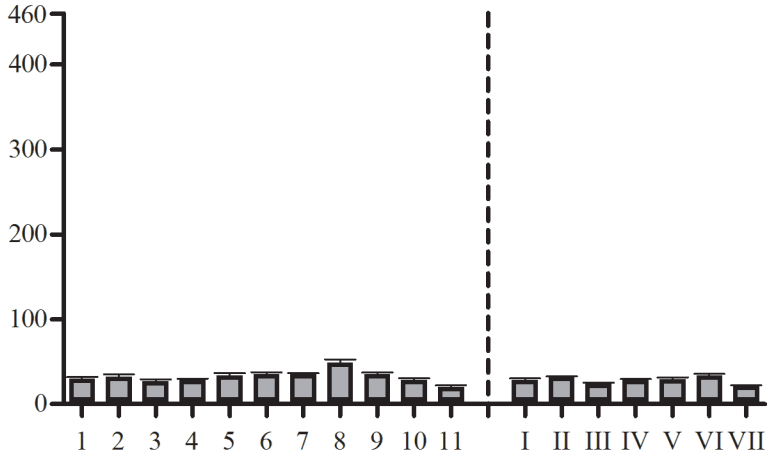




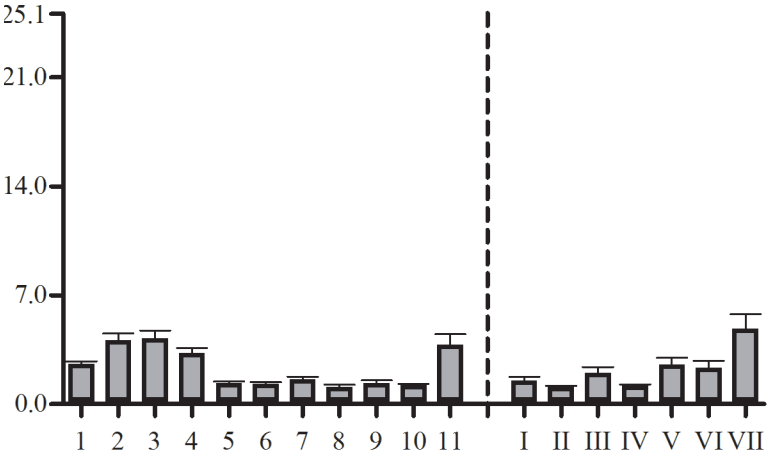
TESVI graphical representation

(a proportional ordinate scaling)

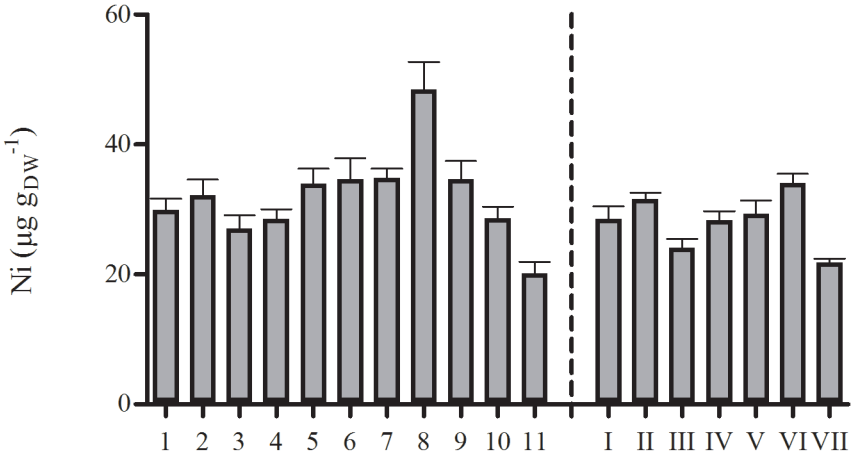
Ni

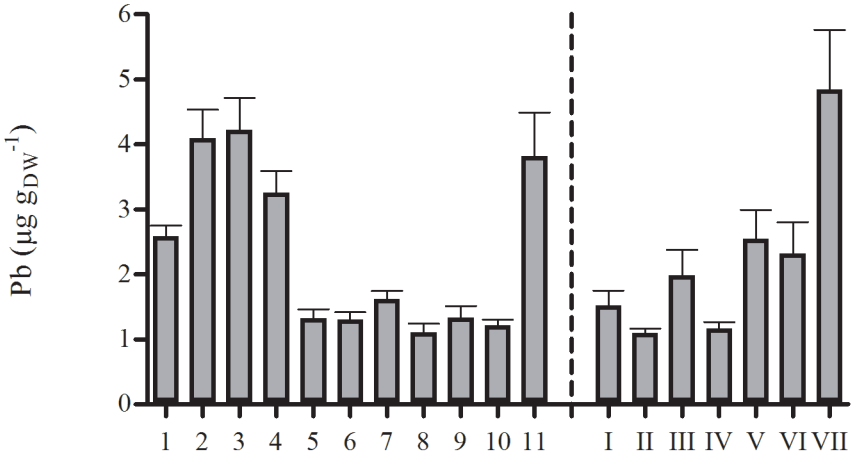


Pb



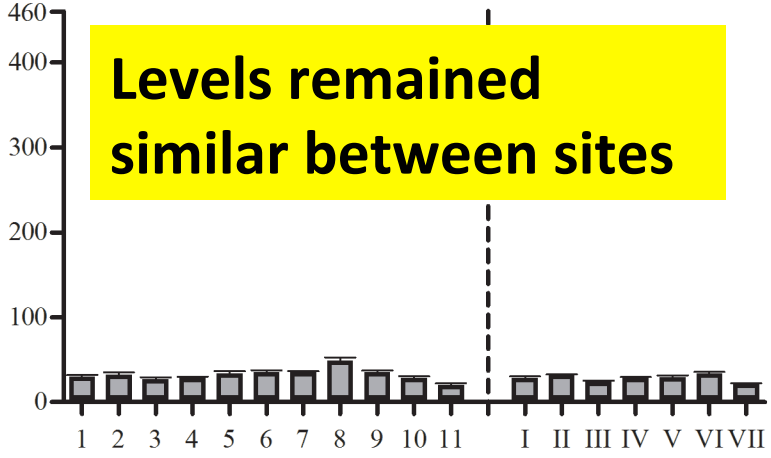
Classic graphical representation





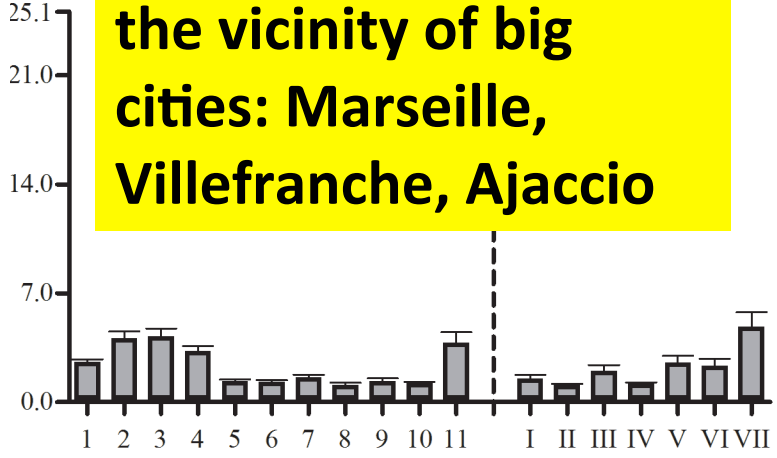
TESVI graphical representation

Ni

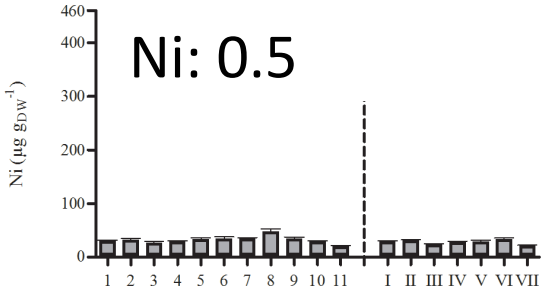


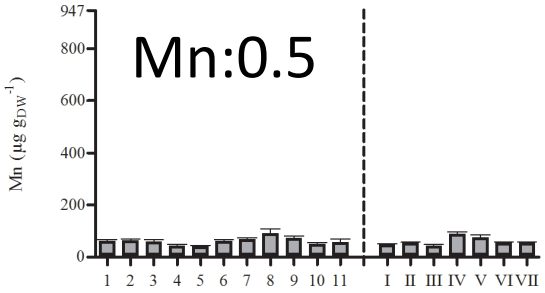
Levels remained similar between sites

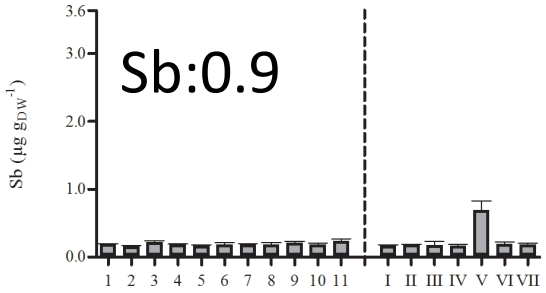
Pb

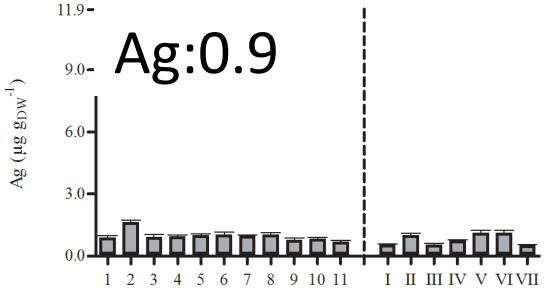


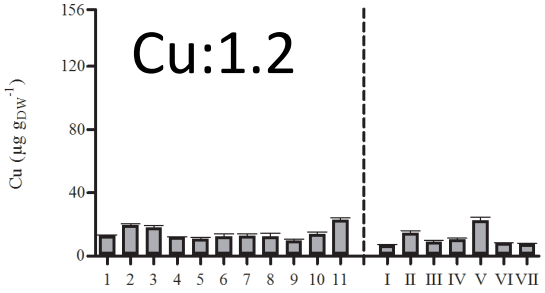
Pb contaminations in the vicinity of big cities: Marseille, Villefranche, Ajaccio

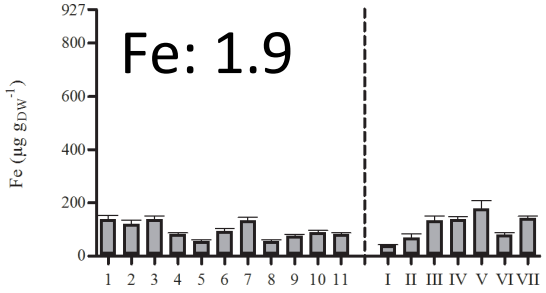

Ni: 0.5
Ni (µg gDW-1)
460
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

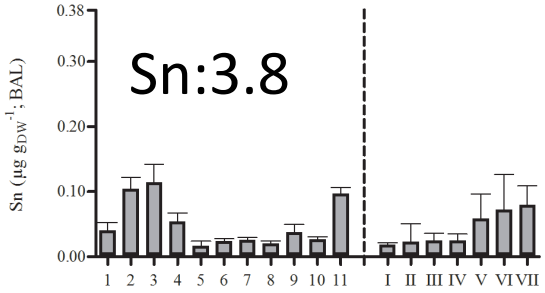

Mn:0.5
Mn (µg gDW-1)
947
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

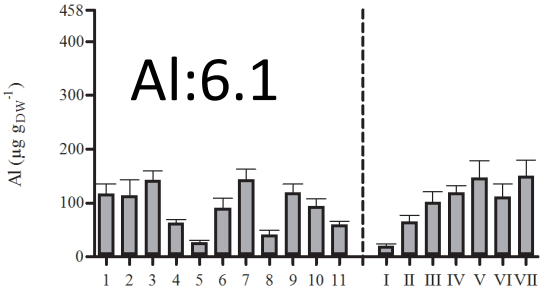

Sb:0.9
Sb (µg gDW-1)
3.6
3.0
2.0
1.0
0.0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

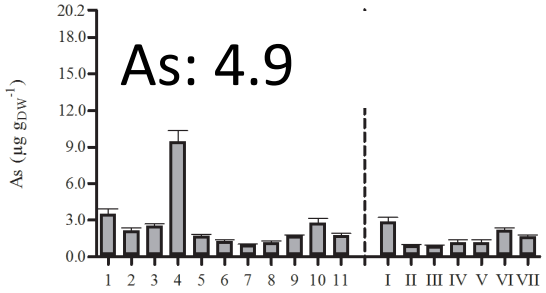

Ag:0.9
Ag (µg gDW-1)
11.9
9.0
6.0
3.0
0.0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

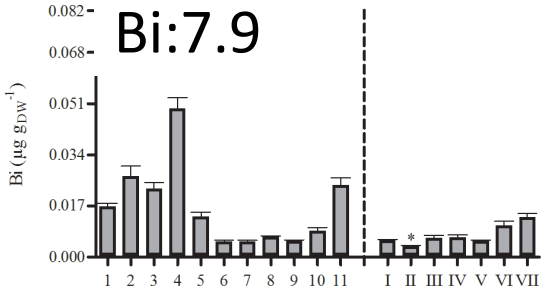

Cu:1.2
Cu (µg gDW-1)
156
120
80
40
0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

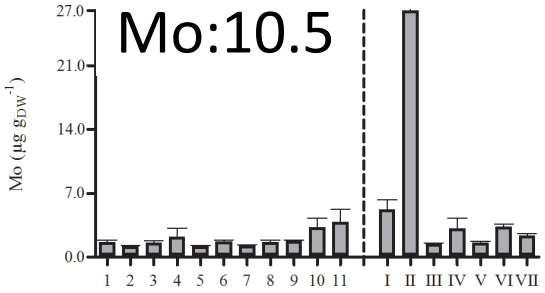

Fe: 1.9
Fe (µg gDW-1)
927
800
600
400
200
0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

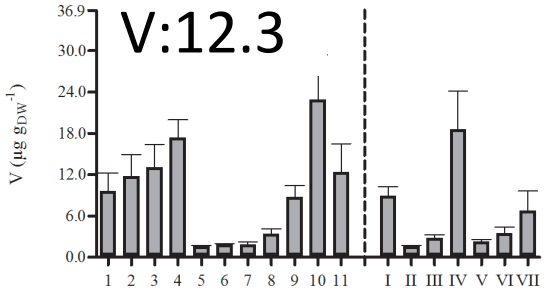

Sn:3.8
Sn (µg gDW-1; BAL)
0.38
0.30
0.20
0.10
0.00
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

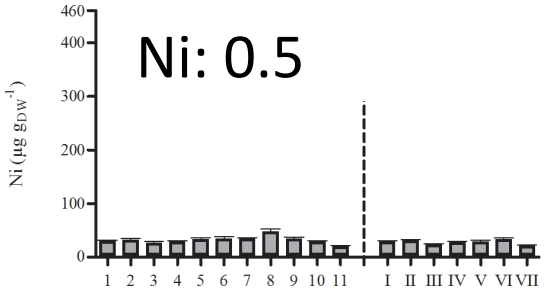

Al:6.1
Al (µg gDW-1)
458
400
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

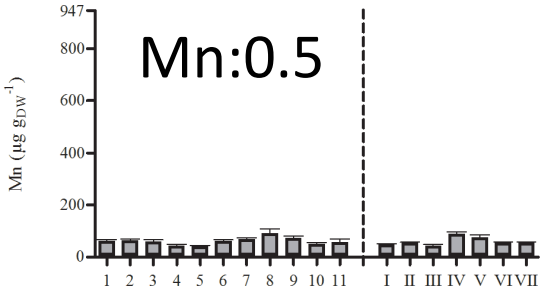

As: 4.9
As (µg gDW-1)
20.2
18.0
15.0
12.0
9.0
6.0
3.0
0.0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

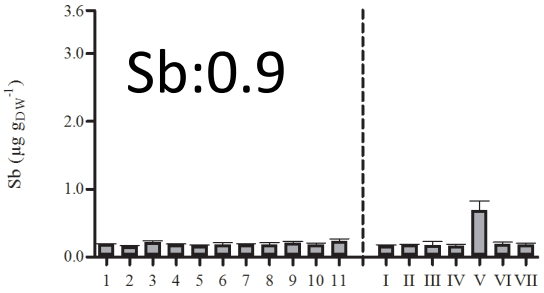

Bi:7.9
Bi (µg gDW-1)
0.082
0.068
0.051
0.034
0.017
0.000
*
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

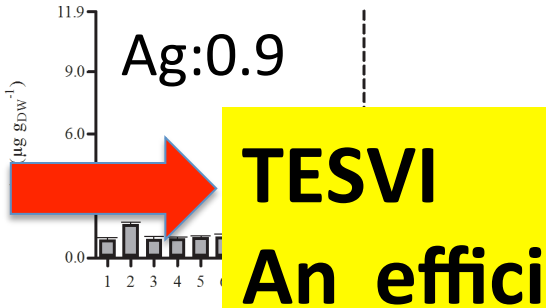

Mo:10.5
Mo (µg gDW-1)
27.0
21.0
14.0
7.0
0.0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

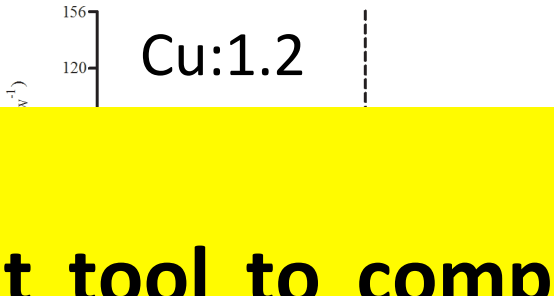

V:12.3
V (µg gDW-1)
36.9
30.0
24.0
18.0
12.0
6.0
0.0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII





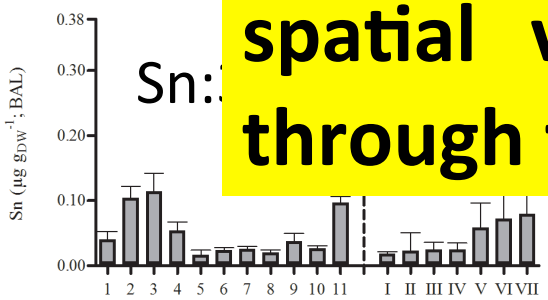


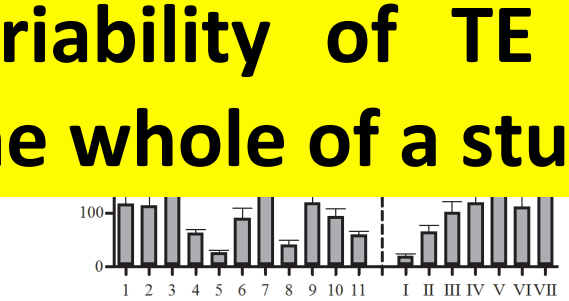


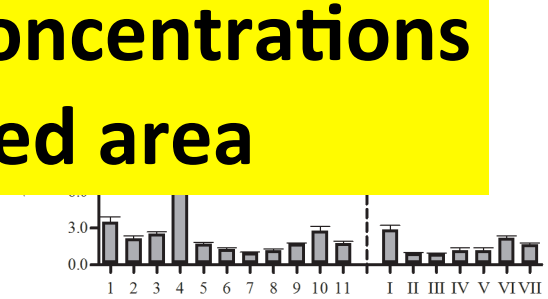


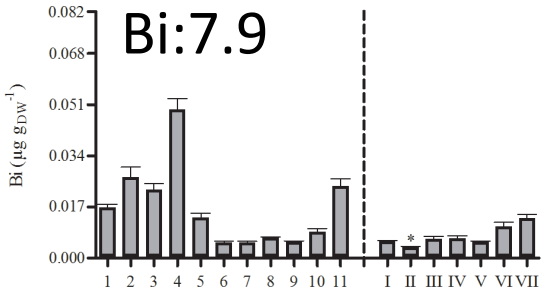
TESVI

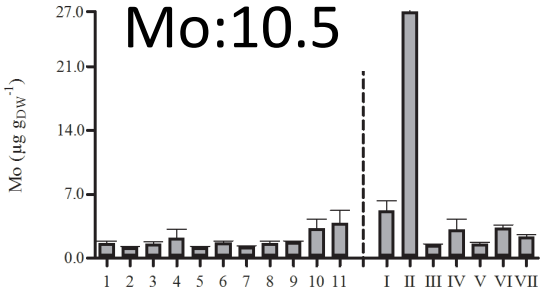
An efficient tool to compare the overall spatial variability of TE concentrations through the whole of a studied area

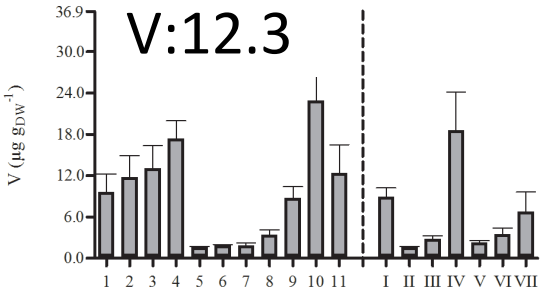


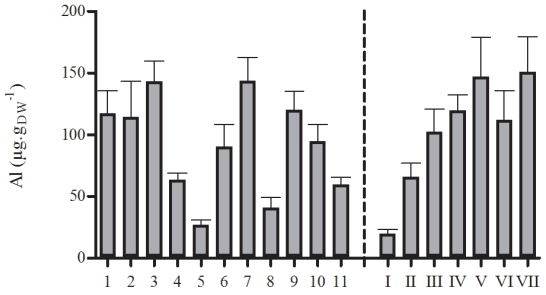


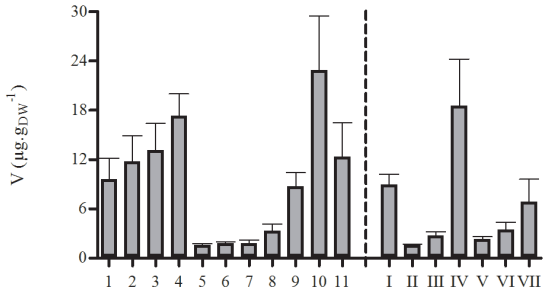


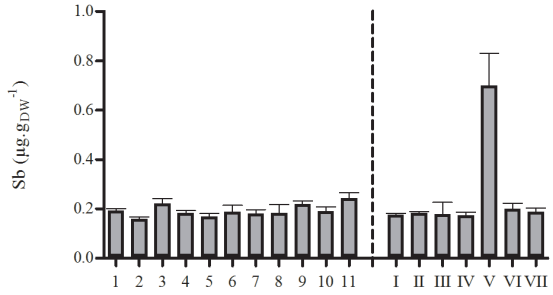




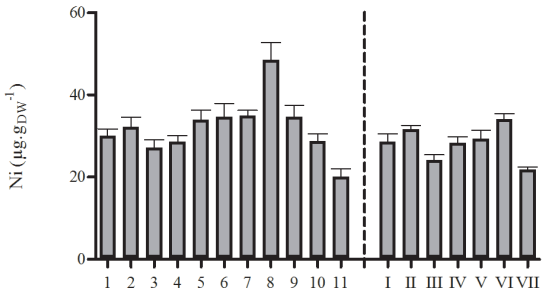


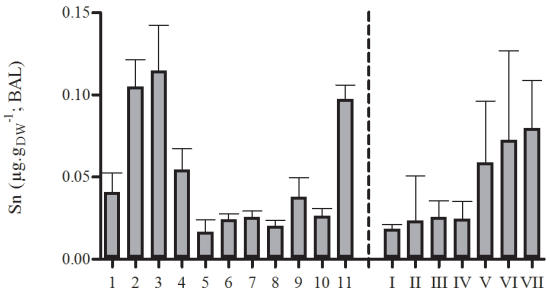


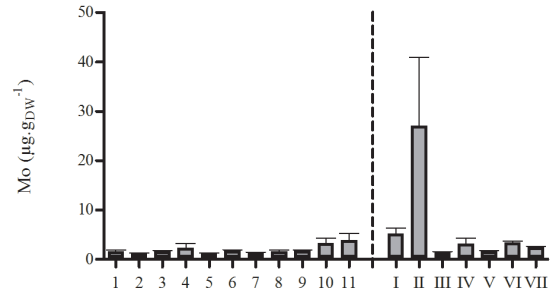




2. How to compare global pollution levels in TEs between several monitored sites ?





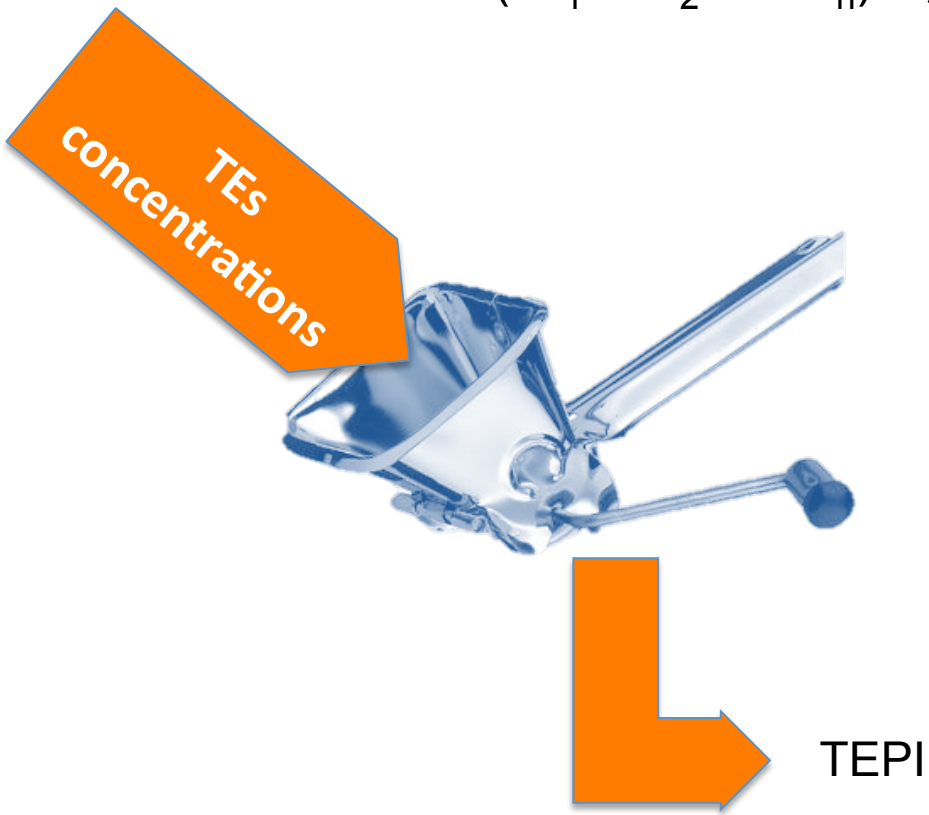


Trace Element Pollution Index

How to compare global pollution levels in TEs between several monitored sites ?

Trace Element Pollution Index (TEPI)

$$TEPI = (Cf_1 * Cf_2 \ldots Cf_n)^{1/n},$$



T
E
P
I

How to compare global pollution levels in TEs between several monitored sites ?

TEPI

Trace Element Pollution Index (TEPI)

$$TEPI = (Cf_1 * Cf_2 \ldots Cf_n)^{1/n},$$

a weighted version of the Metal Pollution Index (MPI) of Usero et al. (1996, MPB)

where:

- Cf_n is the mean normalized concentration of the TE n in a given monitored site.

The highest the index value, the more the monitored site is globally contaminated in TEs compared to the others.

How to compare global pollution levels in TEs between several monitored sites ?

TEPI

Trace Element Pollution Index (TEPI)

$$TEPI = (Cf_1 * Cf_2 \ldots Cf_n)^{1/n},$$

a weighted version of the Metal Pollution Index (MPI) of Usero et al. (1996, MPB)

where:

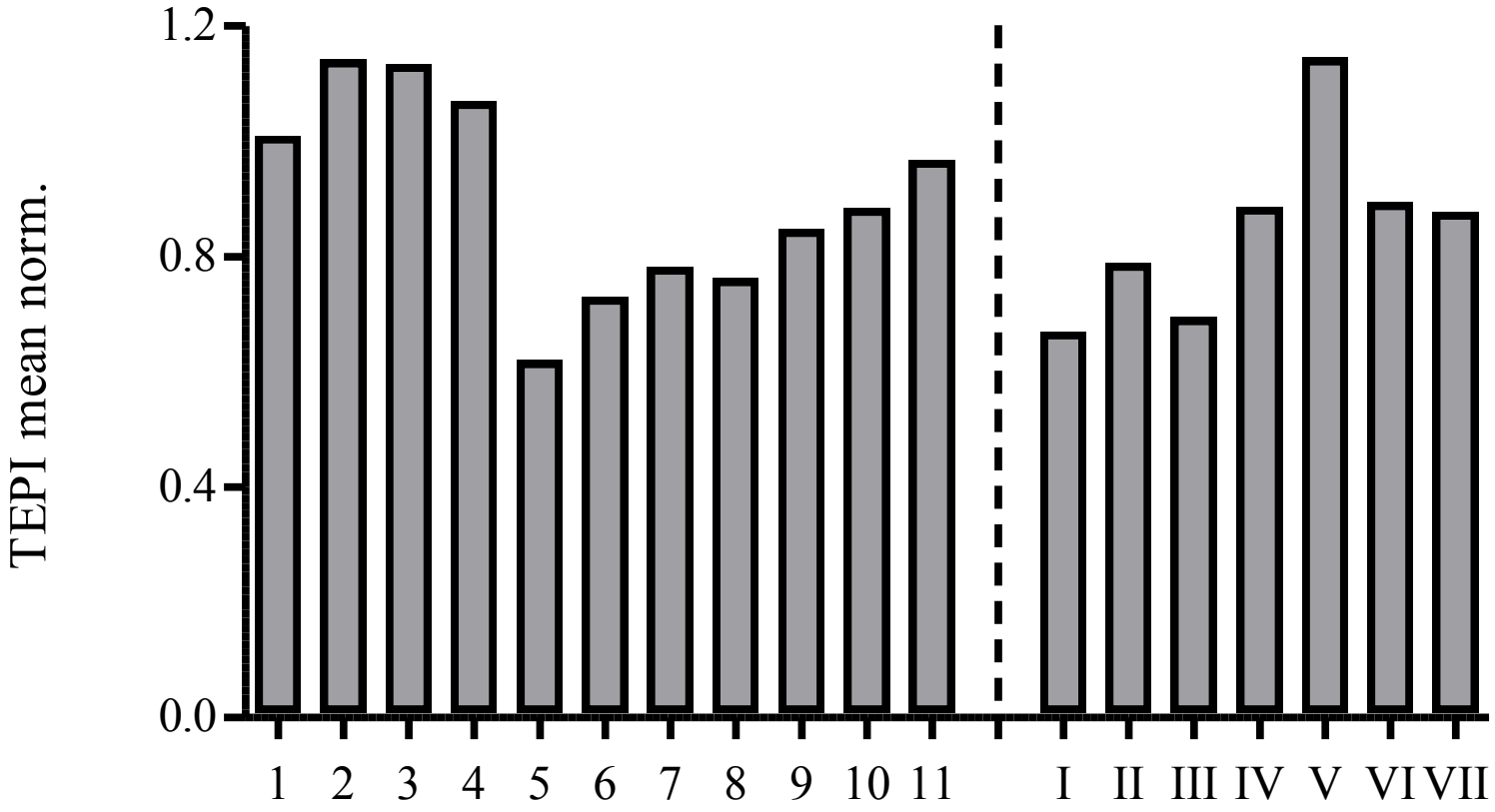
- Cf_n is the mean normalized concentration of the TE n in a given monitored site.

(divise la moyenne en 1 ET d'un site par la moyenne des moyennes des 18 sites échantillonnés)

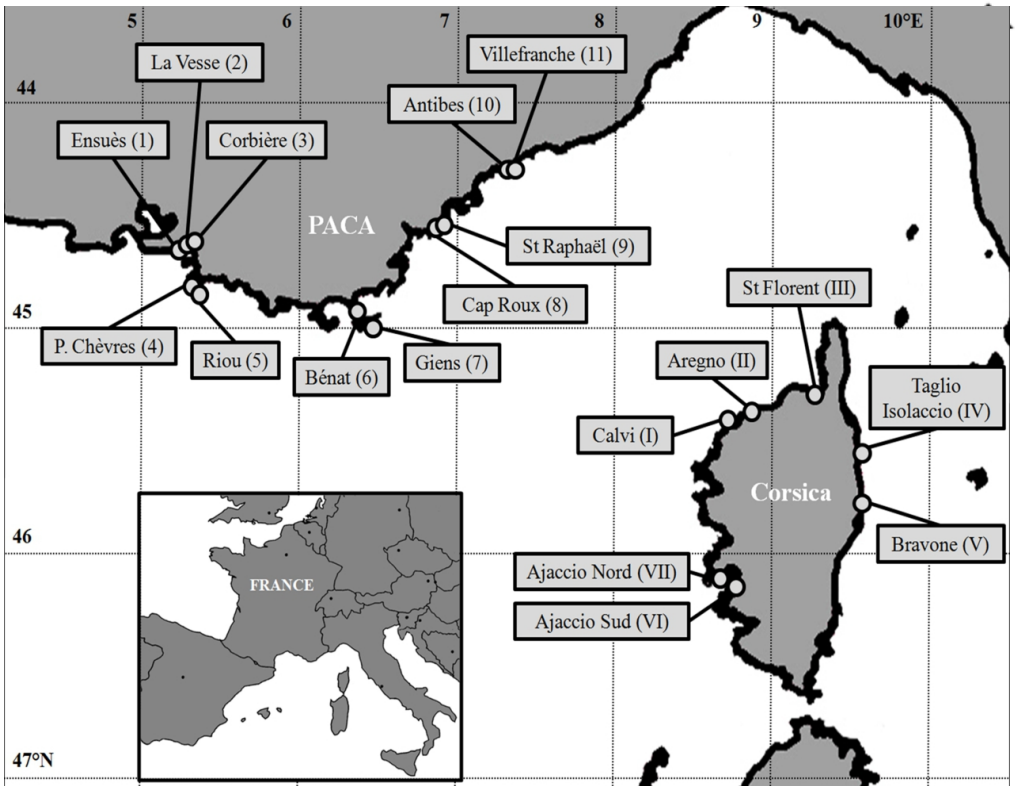
The highest the index value, the more the monitored site is globally contaminated in TEs compared to the others.

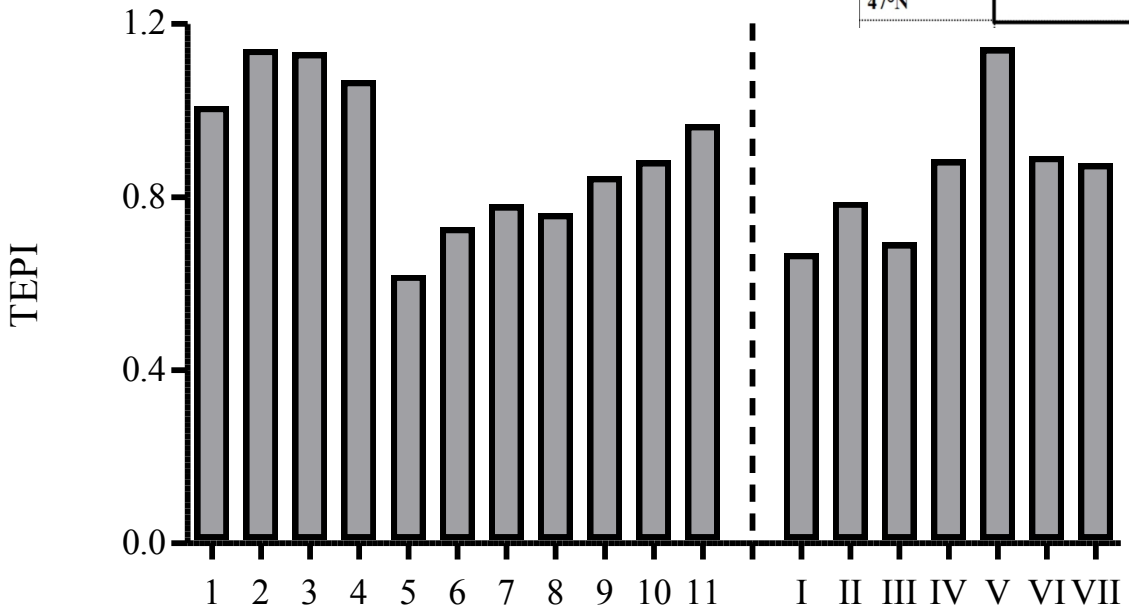
TEPI for the French Mediterranean littoral

TEPI

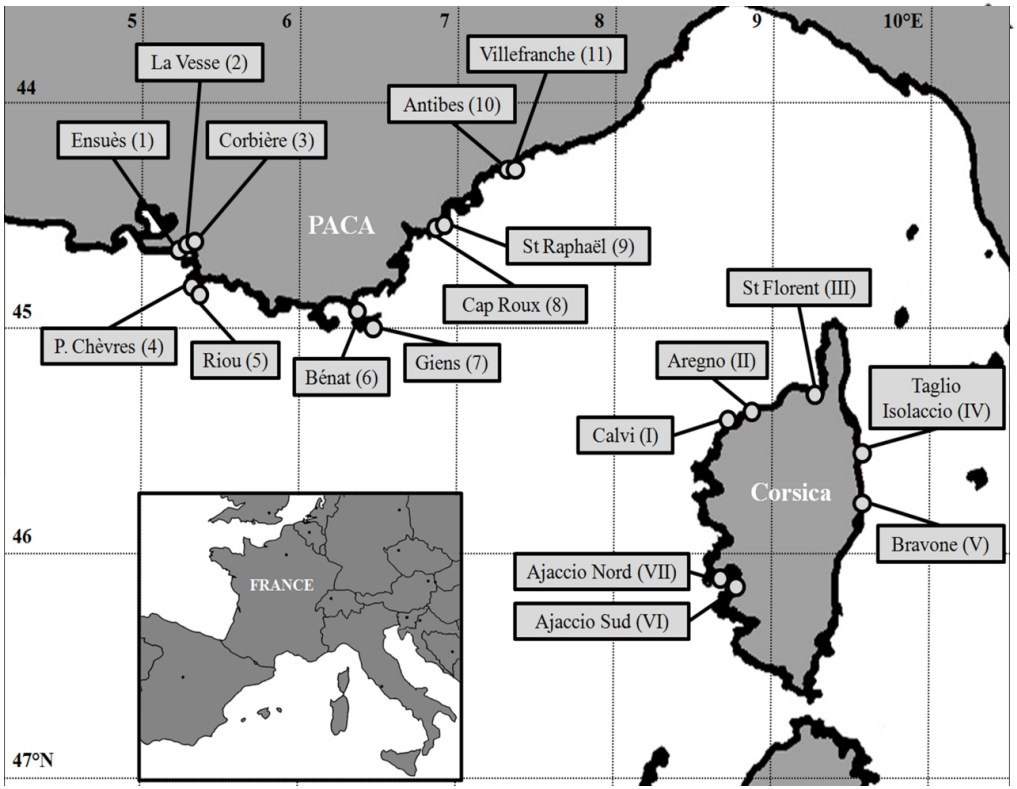


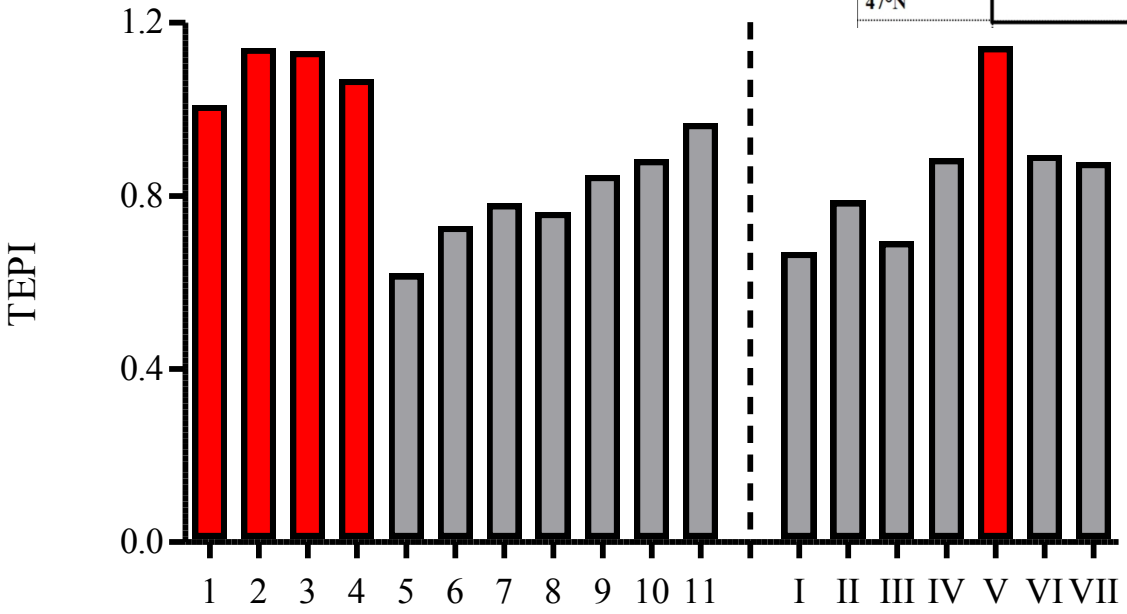
P. oceanica


5
6
7
8
9
10°E
44
45
46
47°N
La Vesse (2)
Villefranche (11)
Antibes (10)
Ensuès (1)
Corbière (3)
PACA
St Raphaël (9)
St Florent (III)
Cap Roux (8)
P. Chèvres (4)
Riou (5)
Bénat (6)
Giens (7)
Aregno (II)
Taglio Isolaccio (IV)
Calvi (I)
Corsica
FRANCE
Bravone (V)
Ajaccio Nord (VII)
Ajaccio Sud (VI)


TEPI
1.2
0.8
0.4
0.0
1 2 3 4 5 6 7 8 9 10 11
I II III IV V VI VII

P. oceanica

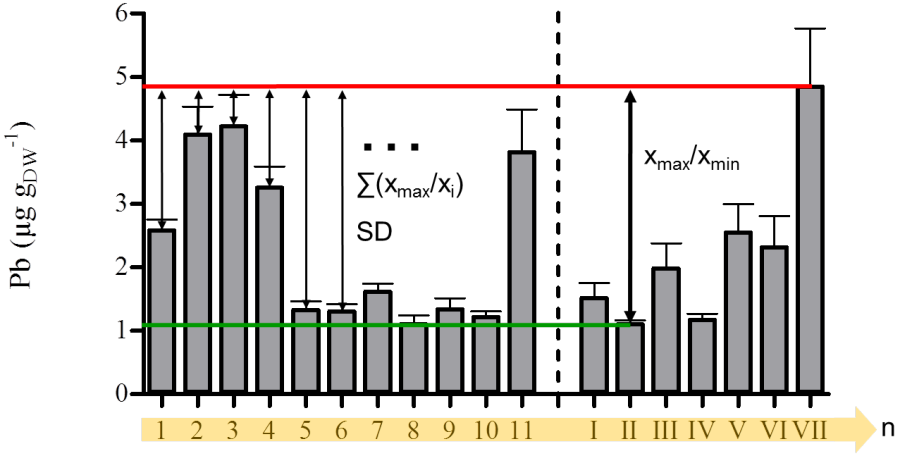

5
6
7
8
9
10°E
44
45
46
47°N
La Vesse (2)
Villefranche (11)
Antibes (10)
Ensuès (1)
Corbière (3)
PACA
St Raphaël (9)
St Florent (III)
Cap Roux (8)
P. Chèvres (4)
Riou (5)
Bénat (6)
Giens (7)
Aregno (II)
Taglio Isolaccio (IV)
Calvi (I)
Corsica
Bravone (V)
FRANCE
Ajaccio Nord (VII)
Ajaccio Sud (VI)


TEPI
1.2
0.8
0.4
0.0
1 2 3 4 5 6 7 8 9 10 11 I II III IV V VI VII

Conclusion

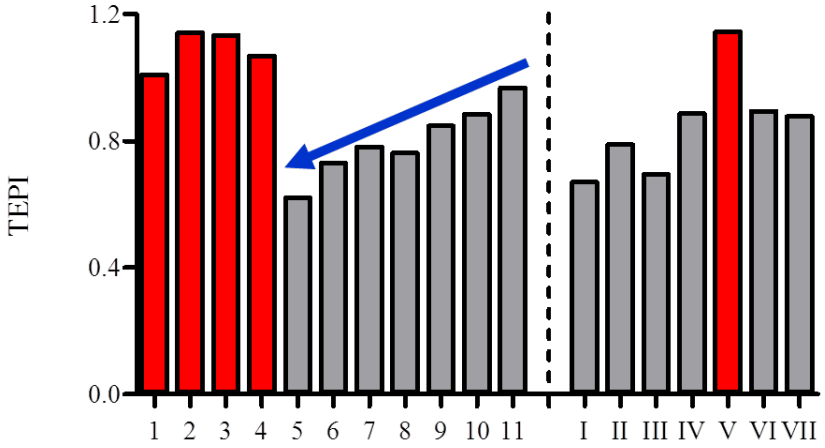
Trace Element Spatial Variation Index

$$TESVI = [(x_{max}/x_{min}) / (\sum(x_{max}/x_i)/n)] * SD$$



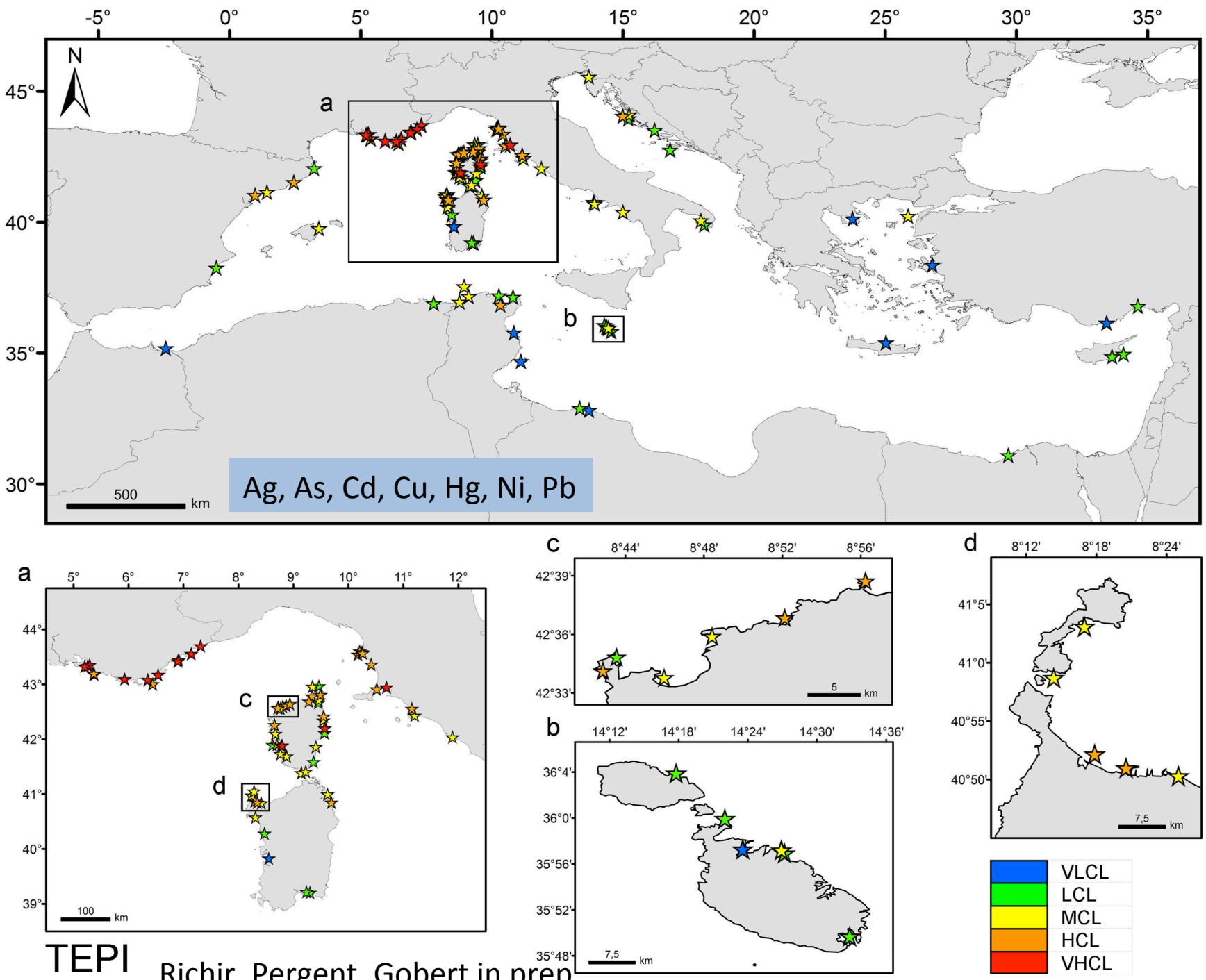
Trace Element Pollution Index

$$TEPI = (Cf_1 * Cf_2 \ldots Cf_n)^{1/n}$$



For A TE
High TESVI
A problem with a TE
At your spatial studied area

For a site
High TEPI
A problem on a site in comparison with the others



TEPI

Richir, Pergent, Gobert in prep


Thank you for
your attention