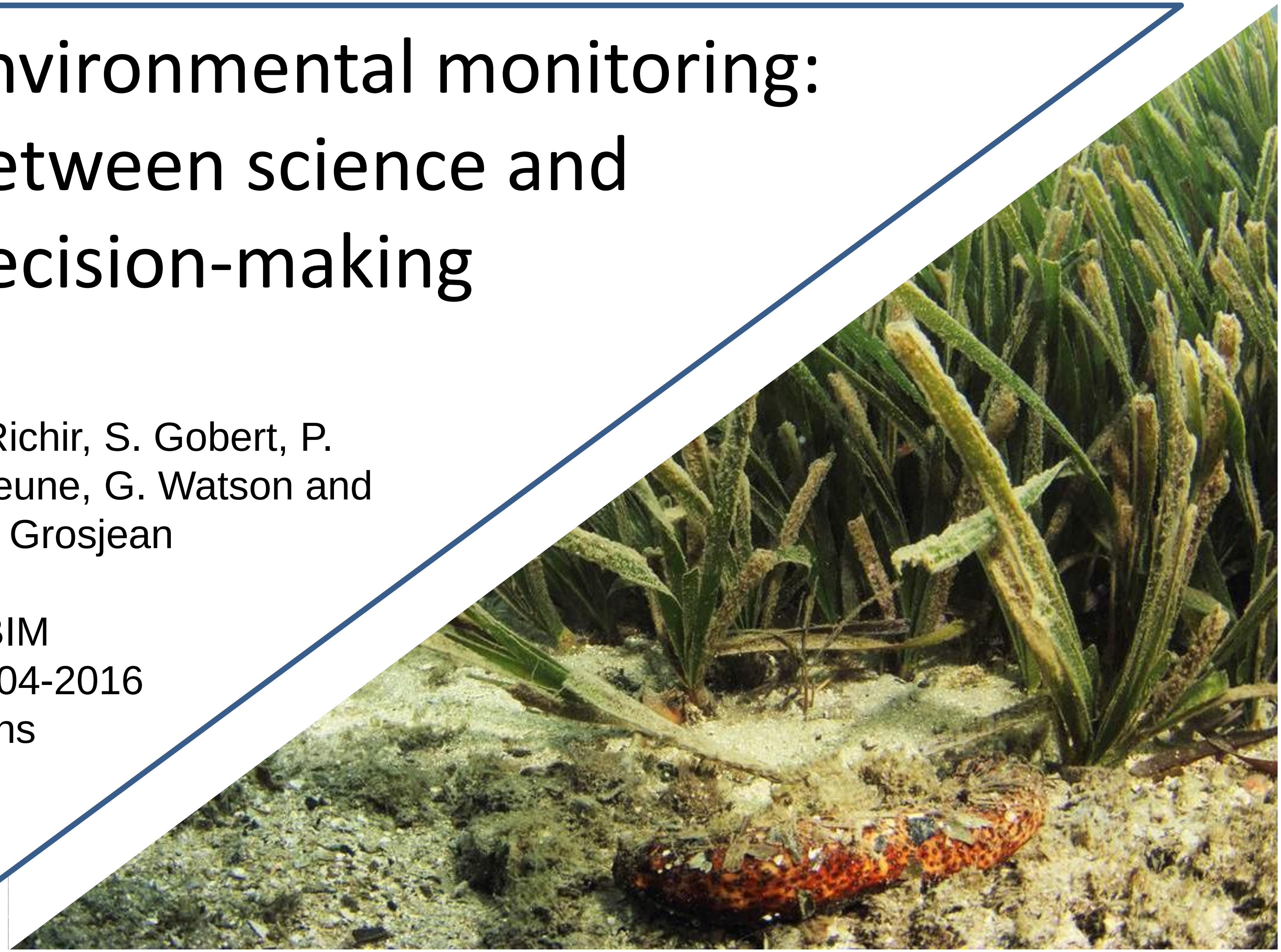
Environmental monitoring: between science and decision-making

J. Richir, S. Gobert, P. Lejeune, G. Watson and Ph. Grosjean

CIBIM
13-04-2016
Mons



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PERIODIC TABLE of the ELEMENTS

DEPARTMENT OF SCIENCE AND TECHNOLOGY

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ALKALI METALS	
ALKALI EARTH METALS	
TRANSITION METALS	
OTHER METALS	
OTHER NONMETALS	
HALOGENS	
NOBLE GASSES	
RARE EARTH METALS	

H Hydrogen 1 1.01 — Symbol; Element name; Atomic number; Atomic mass

At room temperature the element is:

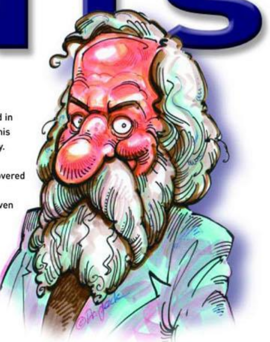
- Gas
- Liquid
- Natural solid
- Man-made solid (synthetic)

DMITRI MENDELEYEV (1834 – 1907)

The Russian chemist, Dmitri Mendeleyev, was the first to observe that if elements were listed in order of atomic mass, they showed regular (periodical) repeating properties. He formulated his discovery in a periodic table of elements, now regarded as the backbone of modern chemistry.

The crowning achievement of Mendeleyev's periodic table lay in his prophecy of then, undiscovered elements. In 1869, the year he published his periodic classification, the elements gallium, germanium and scandium were unknown. Mendeleyev left spaces for them in his table and even predicted their atomic masses and other chemical properties. Six years later, gallium was discovered and his predictions were found to be accurate. Other discoveries followed and their chemical behaviour matched that predicted by Mendeleyev.

This remarkable man, the youngest in a family of 17 children, has left the scientific community with a classification system so powerful that it became the cornerstone in chemistry teaching and the prediction of new elements ever since.
In 1955, element 101 was named after him: Md, Mendelevium.



	IA 1	IIA 2	IIIB 3	IVB 4	VB 5	VIB 6	VIIB 7	VIII 8	VIII 9	VIII 10	IB 11	IIB 12	IIIA 13	IVA 14	VA 15	VIA 16	VIIA 17	VIIIA 18
1	H Hydrogen 1 1.01																	He Helium 2 4.00
2	Li lithium 3 6.94	Be Beryllium 4 9.01											B Boron 5 10.81	C Carbon 6 12.01	N Nitrogen 7 14.01	O Oxygen 8 16.00	F Fluorine 9 19.00	Ne Neon 10 20.18
3	Na Sodium 11 22.99	Mg Magnesium 12 24.31											Al Aluminium 13 26.98	Si Silicon 14 28.09	P Phosphorus 15 30.97	S Sulphur 16 32.06	Cl Chlorine 17 35.45	Ar Argon 18 39.95
4	K Potassium 19 39.10	Ca Calcium 20 40.08	Sc Scandium 21 44.96	Ti Titanium 22 47.88	V Vanadium 23 50.94	Cr Chromium 24 52.00	Mn Manganese 25 54.94	Fe Iron 26 55.85	Co Cobalt 27 58.93	Ni Nickel 28 58.69	Cu Copper 29 63.55	Zn Zinc 30 65.39	Ga Gallium 31 69.72	Ge Germanium 32 72.61	As Arsenic 33 74.92	Se Selenium 34 78.96	Br Bromine 35 79.90	Kr Krypton 36 83.80
5	Rb Rubidium 37 85.47	Sr Strontium 38 87.62	Y Yttrium 39 88.91	Zr Zirconium 40 91.22	Nb Niobium 41 92.91	Mo Molybdenum 42 95.94	Tc Technetium 43 (98)	Ru Ruthenium 44 101.07	Rh Rhodium 45 102.91	Pd Palladium 46 106.42	Ag Silver 47 107.87	Cd Cadmium 48 112.41	In Indium 49 114.82	Sn Tin 50 118.71	Sb Antimony 51 121.76	Te Tellurium 52 127.60	I Iodine 53 126.90	Xe Xenon 54 131.29
6	Cs Caesium 55 132.91	Ba Barium 56 137.33	Lanthanide Series	Hf Hafnium 72 178.49	Ta Tantalum 73 180.95	W Tungsten 74 183.85	Re Rhenium 75 186.21	Os Osmium 76 190.23	Ir Iridium 77 192.22	Pt Platinum 78 195.08	Au Gold 79 196.97	Hg Mercury 80 200.59	Tl Thallium 81 204.38	Pb Lead 82 207.20	Bi Bismuth 83 208.98	Po Polonium 84 (209)	At Astatine 85 (210)	Rn Radon 86 (222)
7	Fr Francium 87 (223)	Ra Radium 88 (226)	Actinide Series	Rf Rutherfordium 104 (261)	Db Dubnium 105 (262)	Sg Seaborgium 106 (263)	Bh Bohrium 107 (262)	Hs Hassium 108 (265)	Mt Meitnerium 109 (266)									

La Lanthanum 57 138.91	Ce Cerium 58 140.12	Pr Praseodymium 59 140.90	Nd Neodymium 60 144.24	Pm Promethium 61 (145)	Sm Samarium 62 150.36	Eu Europium 63 151.96	Gd Gadolinium 64 157.25	Tb Terbium 65 158.92	Dy Dysprosium 66 162.50	Ho Holmium 67 164.93	Er Erbium 68 167.26	Tm Thulium 69 168.93	Yb Ytterbium 70 173.04	Lu Lutetium 71 174.96
Ac Actinium 89 227.02	Th Thorium 90 232.03	Pa Protactinium 91 231.03	U Uranium 92 238.02	Np Neptunium 93 (237)	Pu Plutonium 94 (244)	Am Americium 95 (243)	Cm Curium 96 (247)	Bk Berkelium 97 (247)	Cf Californium 98 (251)	Es Einsteinium 99 (254)	Fm Fermium 100 (257)	Md Mendelevium 101 (258)	No Nobelium 102 (259)	Lr Lawrencium 103 (260)

Public Understanding of Science Engineering and Technology

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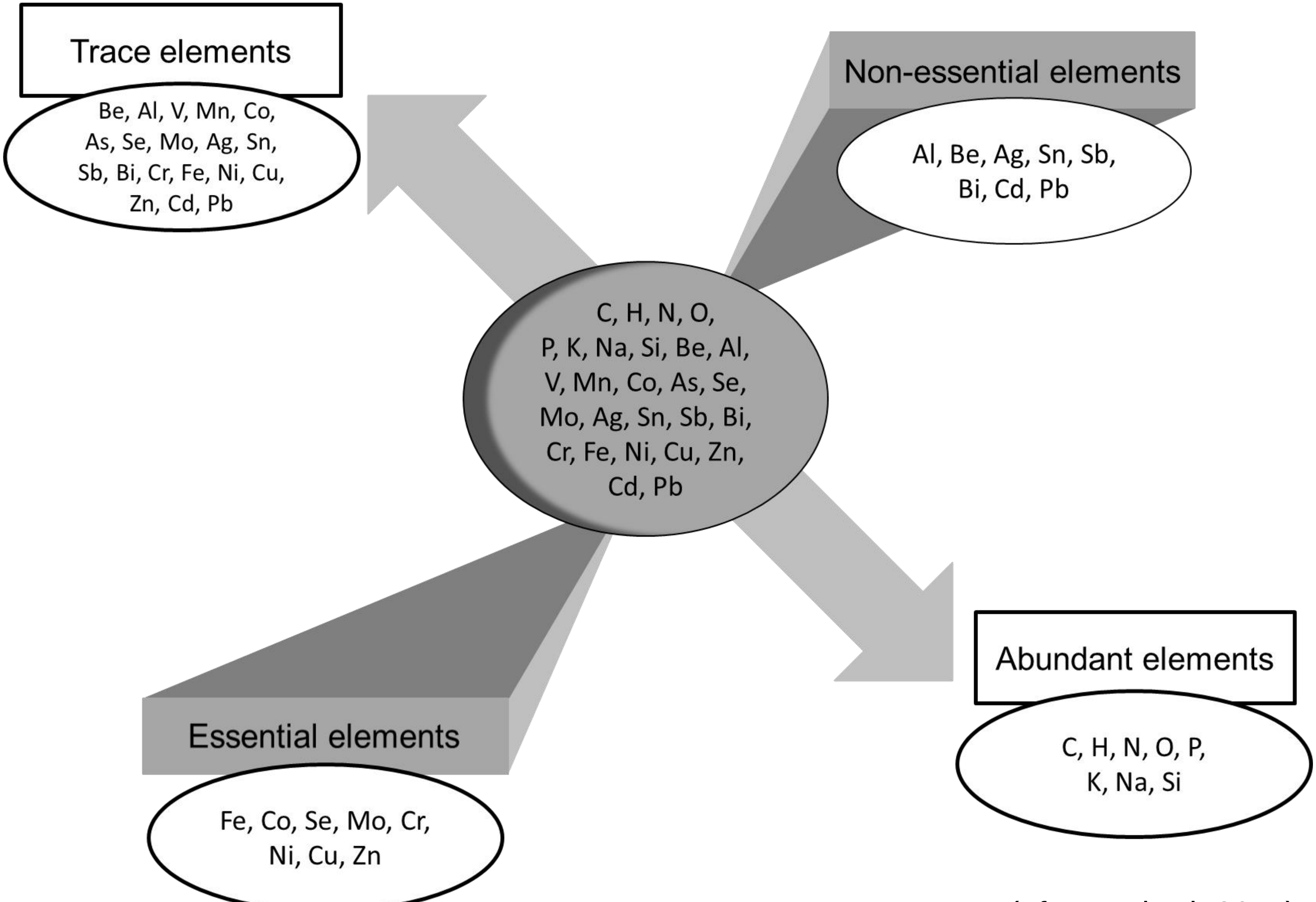
Trace elements



(after Amiard, 2011)

Bioindicator : *Posidonia oceanica*

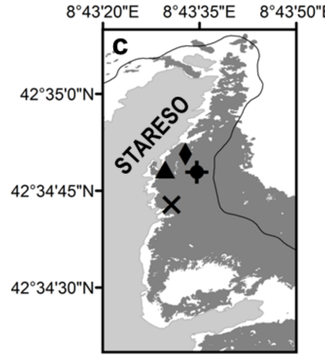
Michel, 2012



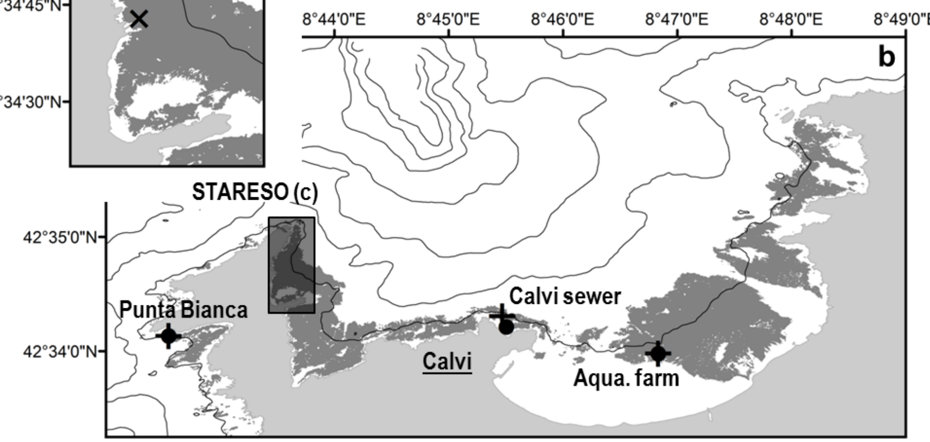


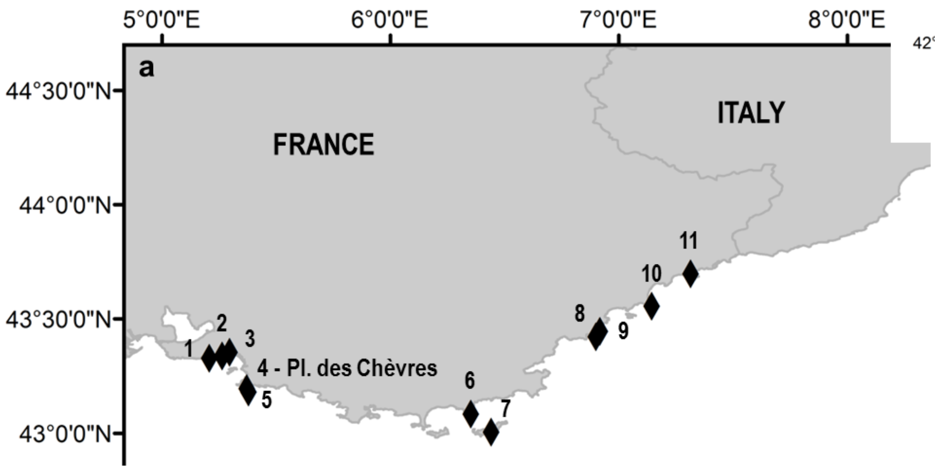
Scale ? Sampling effort ?

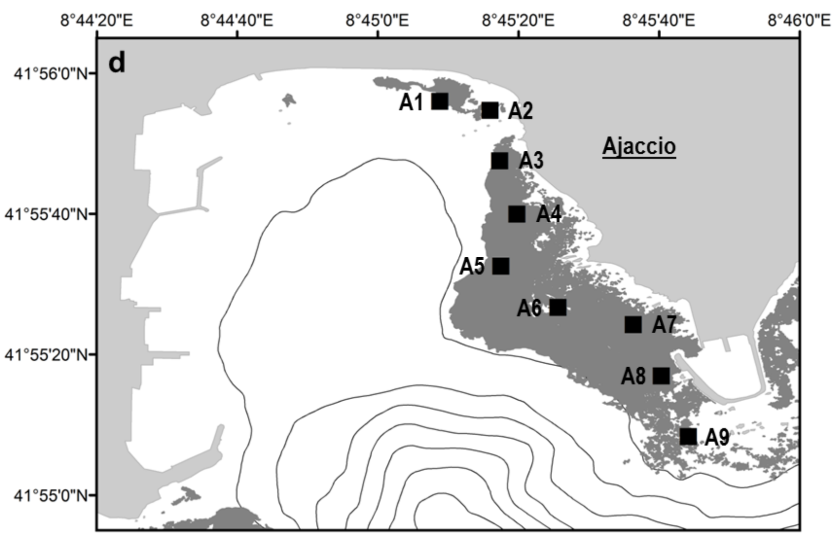
TE accumulation in *P. oceanica* studied at different scales :

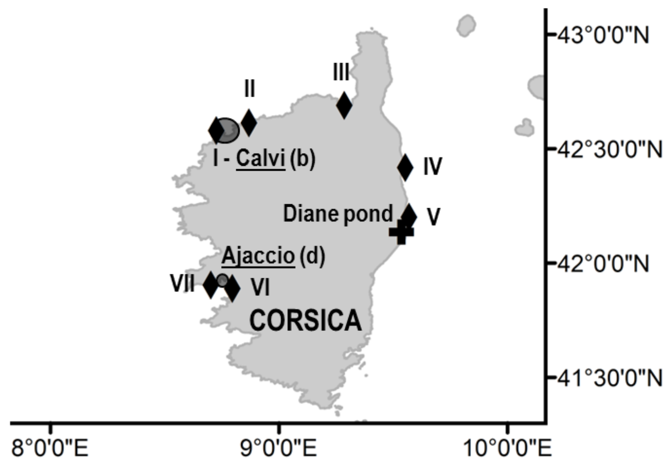


2. In a bay (1 km scale)







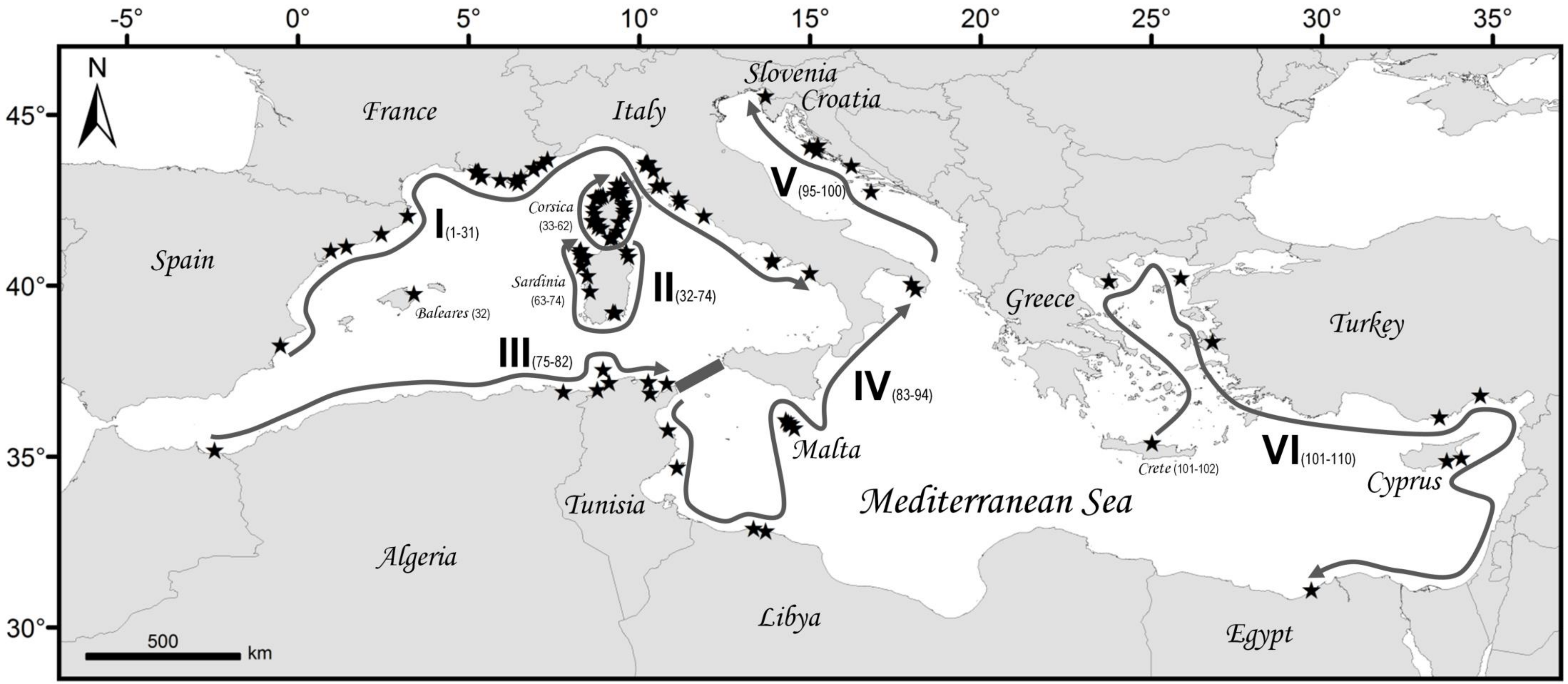


3. Along the French Mediterranean littoral (10-100 km scale)

1. Along a radial (100 m scale)

Scale ? Sampling effort ?

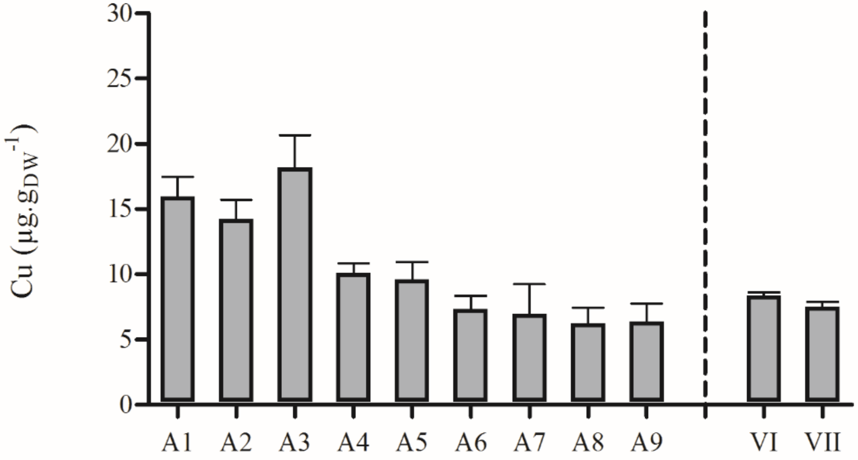
TE accumulation in *P. oceanica* studied at different scales :



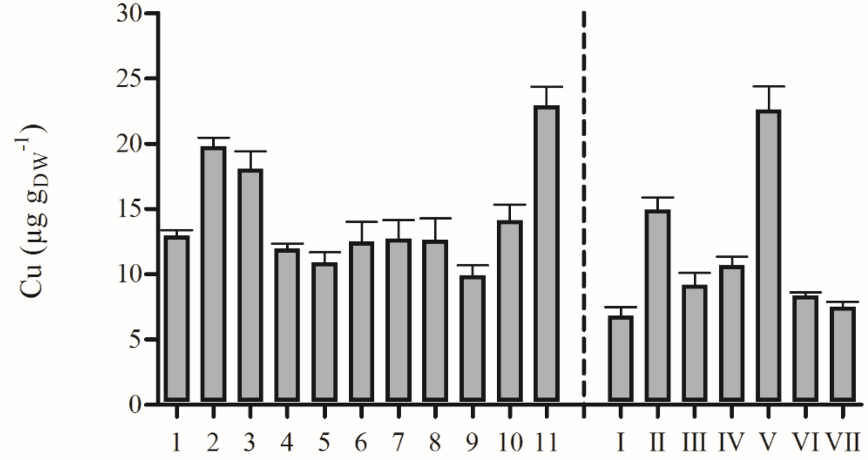
4. Along the whole Mediterranean coastline (100-1000 km scale)

Scale ? Sampling effort ?

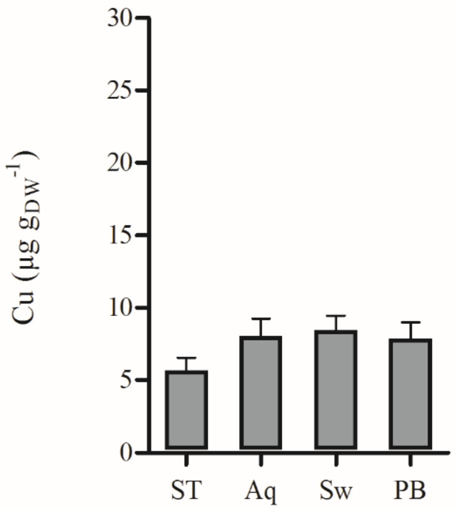
1. Along a radial (100 m)



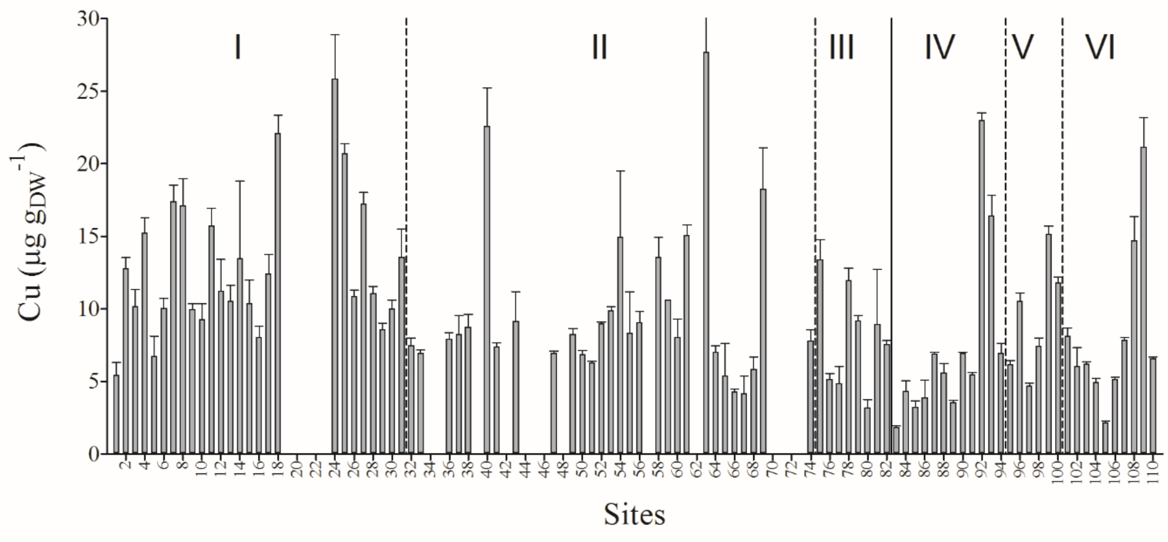
3. Along the French littoral (10-100 km)

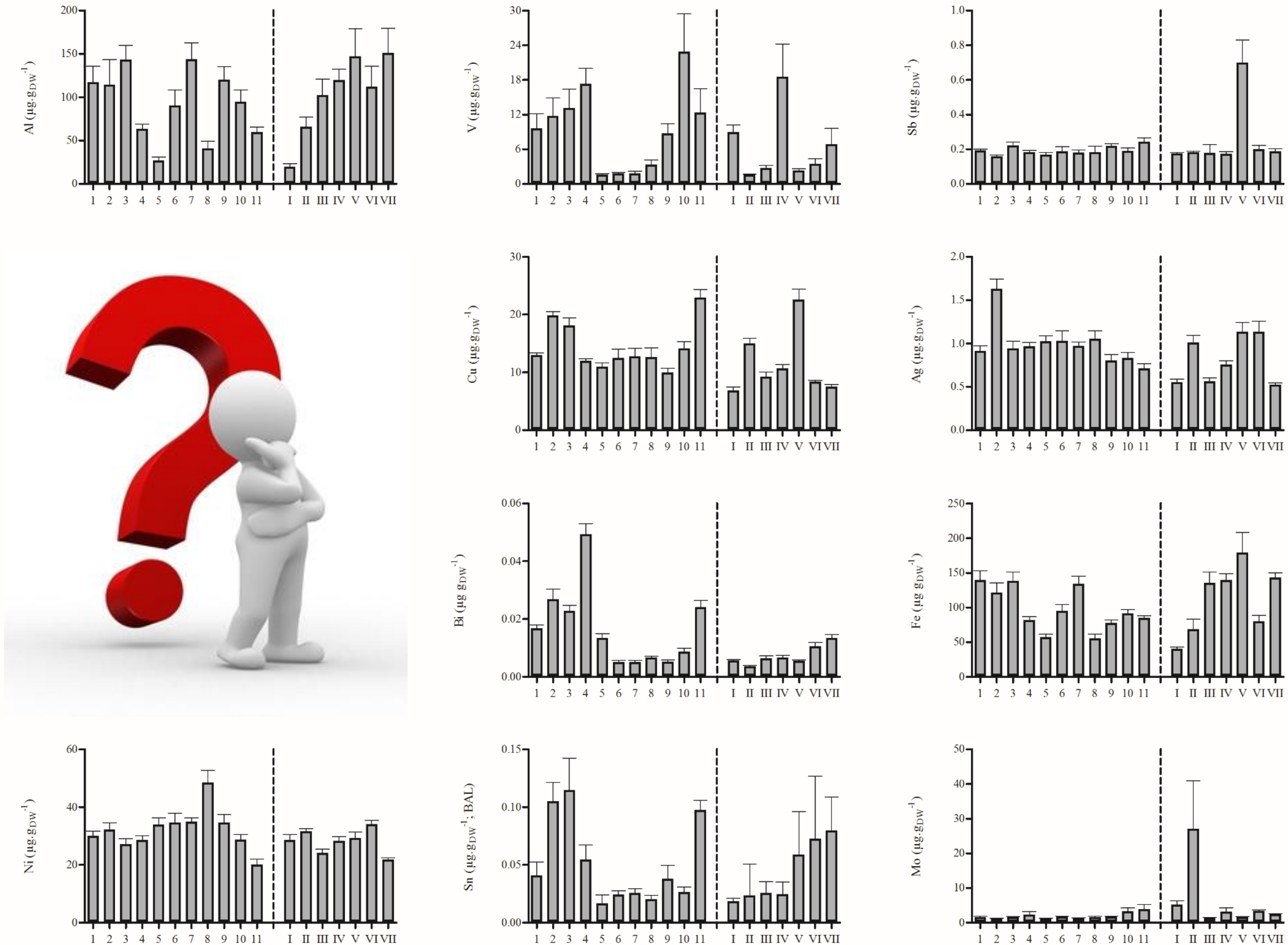


2. In a bay (1 km)



4. Along the Mediterranean coastline (100-1000 km)



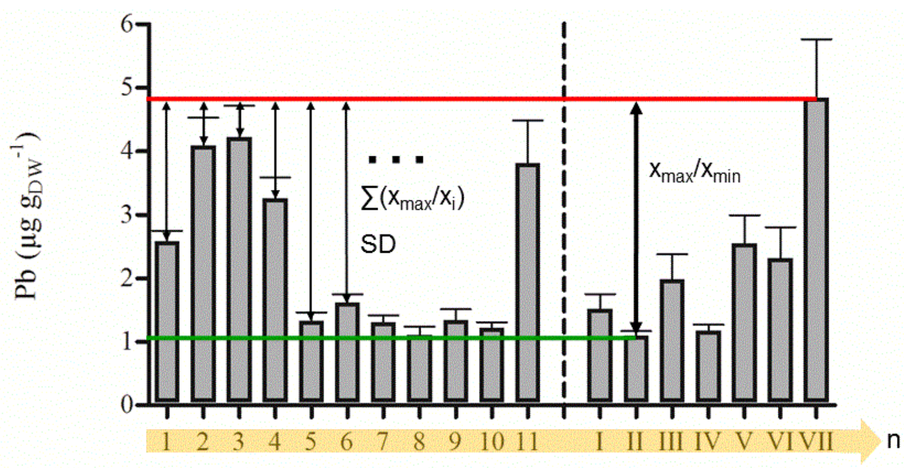


Al (µg.g$_{DW}$$^{-1}$)
V (µg.g$_{DW}$$^{-1}$)
Sb (µg.g$_{DW}$$^{-1}$)
Cu (µg.g$_{DW}$$^{-1}$)
Ag (µg.g$_{DW}$$^{-1}$)
Bi (µg g$_{DW}$$^{-1}$)
Fe (µg g$_{DW}$$^{-1}$)
Ni (µg.g$_{DW}$$^{-1}$)
Sn (µg.g$_{DW}$$^{-1}$; BAL)
Mo (µg.g$_{DW}$$^{-1}$)

Pollution indices

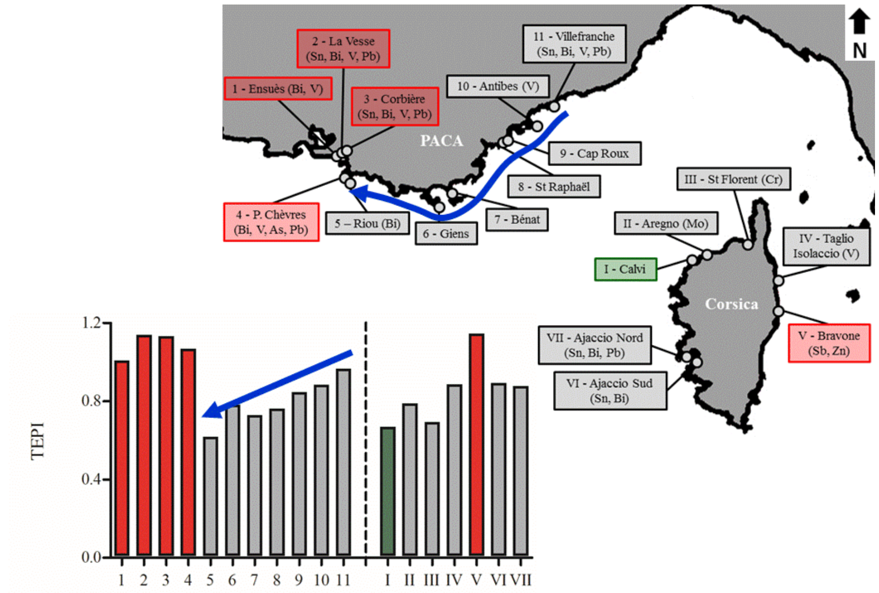
Trace Element Spatial Variation Index

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



Trace Element Pollution Index

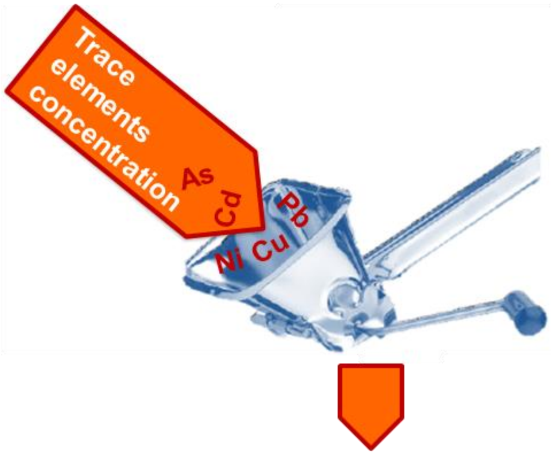
$$TEPI = (Cf_1 * Cf_2 \ldots Cf_n)^{1/n}$$



TESVI and TEPI ⇨ efficient complementary indices to monitor the pollution by TEs. They successfully led:

- to the ordering of TEs according to the overall spatial variability of their environmental levels along the French Mediterranean littoral;
- to the quantification of the global pollution in TEs between monitored sites.

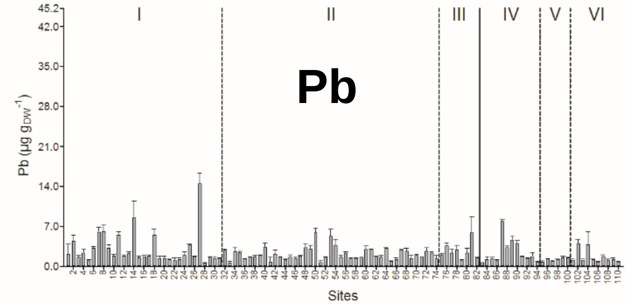
Spatial variability

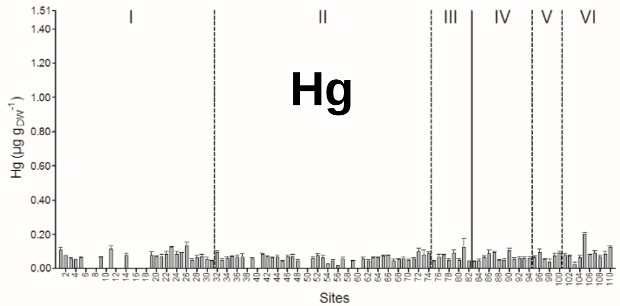


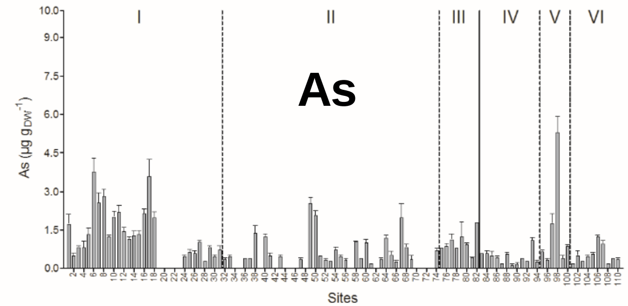
Index values

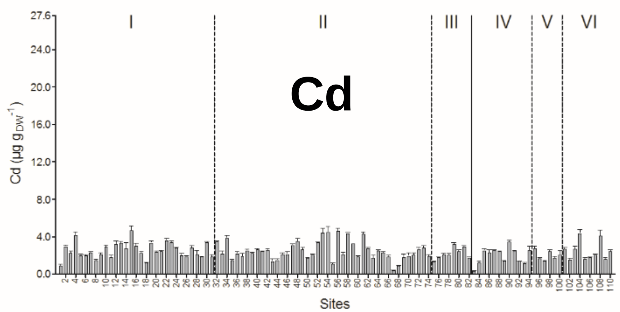
TE	TESVI
Hg	3.9
Cd	8.7
Cu	9.2
Pb	13.3
As	29.4
Ag	34.9
Ni	92.7

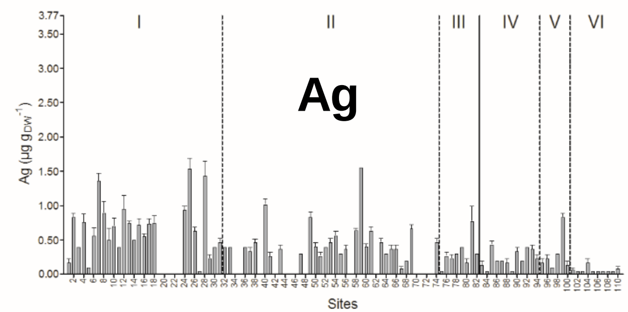
Proportional ordinate **scaling** between TEs:

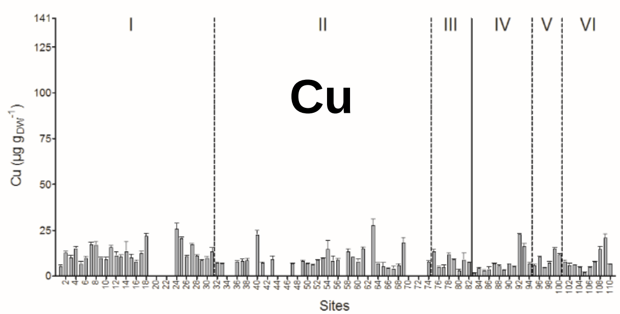


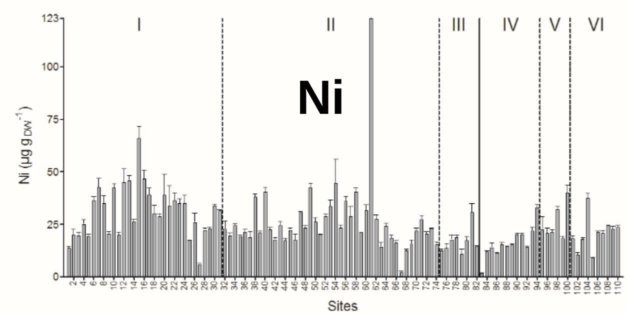




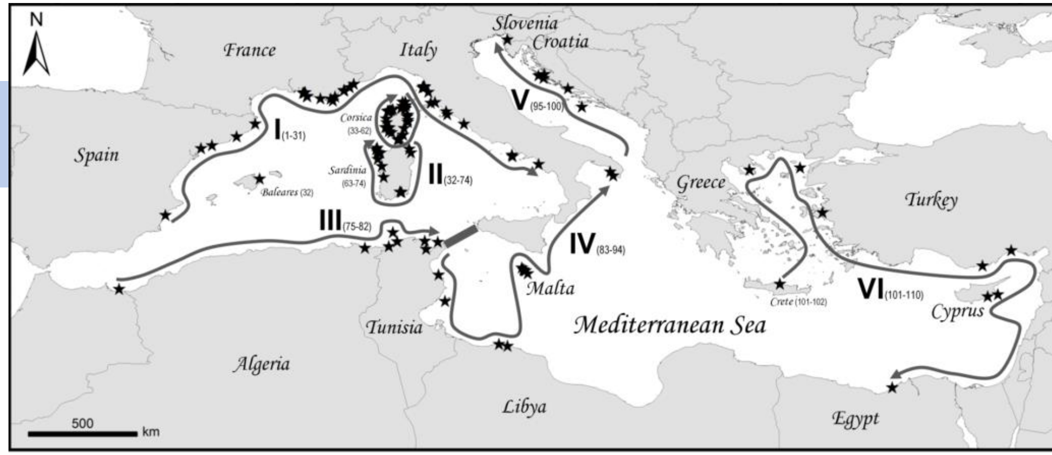


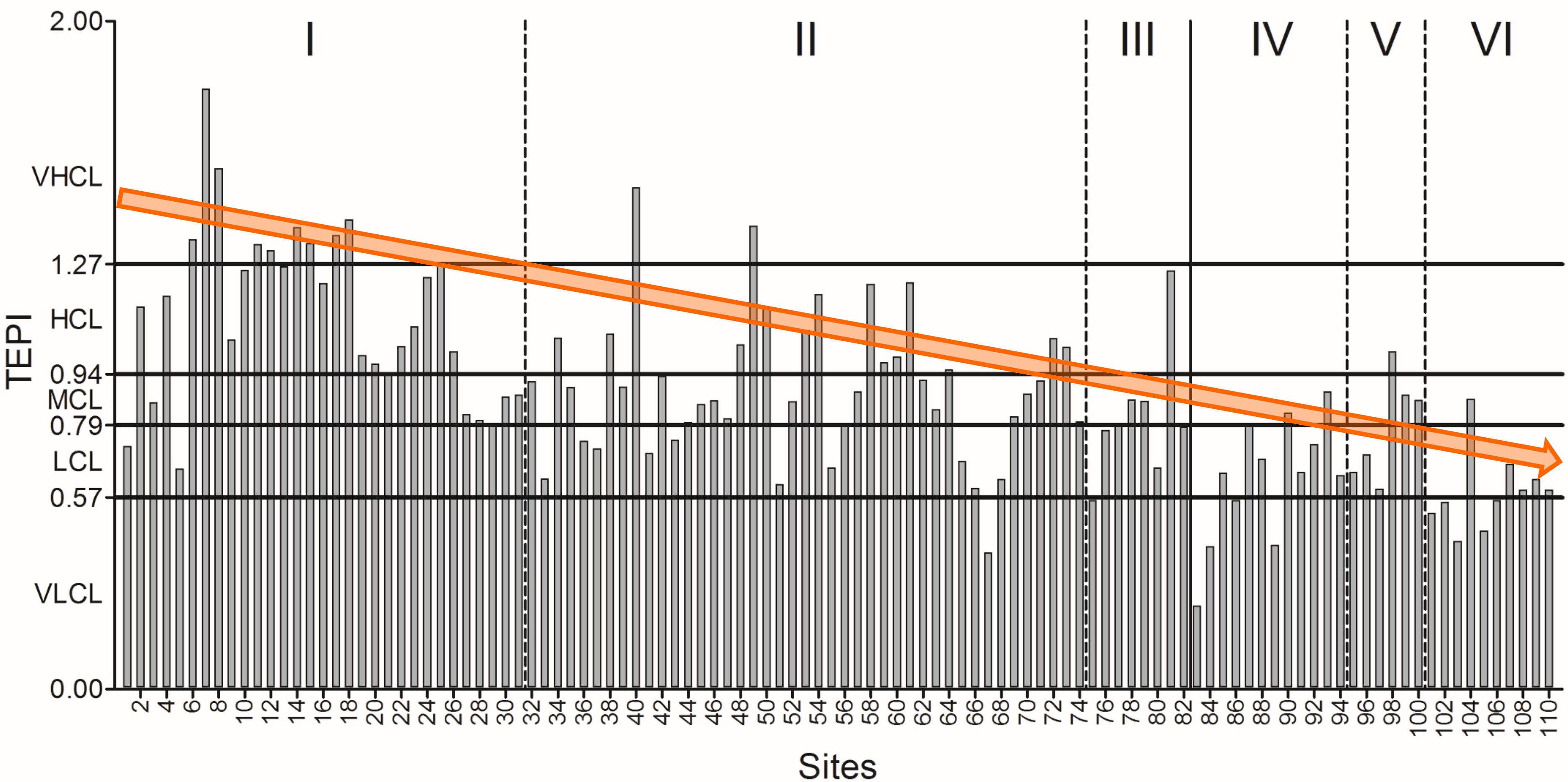






Global contamination





5-level water quality scale

qu. 1	qu. 2	qu. 3	qu. 4
0.6000	1.3333	1.7635	2.9333
0.6333	1.3333	1.7667	2.9667
0.6667	1.3667	1.7682	3.0012
0.7000	1.4000	1.8000	3.1253
0.7667	1.4000	1.8000	3.2113
0.8000	1.4000	1.8018	3.2333
0.8333	1.4333	1.8241	3.2333
0.8333	1.4333	1.8349	3.3667
0.8333	1.4333	1.8667	3.3667
0.8667	1.4511	1.9667	3.4705
0.9000	1.4667	1.9667	3.6000
1.0333	1.5000	2.0000	3.7667
1.0667	1.5000	2.0333	3.8000
1.0667	1.5180	2.1667	3.9000
1.1333	1.5667	2.2000	4.0667
1.1667	1.6000	2.2793	4.0667
1.1667	1.6000	2.3333	4.4333
1.1667	1.6333	2.3333	4.6000
1.2000	1.6333	2.3667	5.3333
1.2333	1.6333	2.4000	5.4790
1.2333	1.6667	2.4333	5.5667
1.2667	1.6667	2.5333	5.9129
1.2667	1.7000	2.6333	5.9250
1.2667	1.7000	2.6667	6.0751
1.2667	1.7000	2.7333	6.1230
1.2667	1.7333	2.9333	7.9000
1.3000	1.7333	2.9333	8.5667
1.3000			14.5000

Quartile means

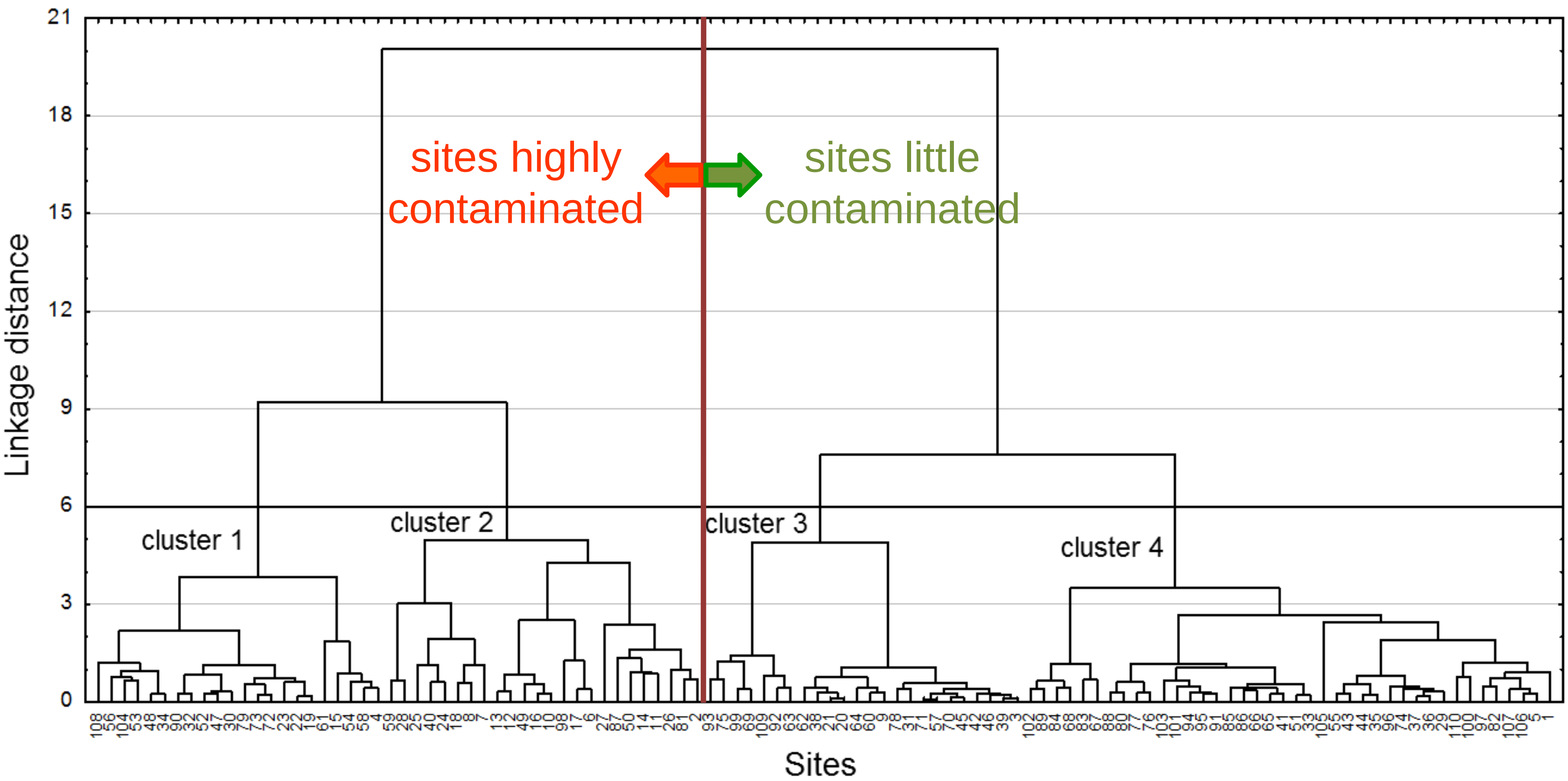
Superior limit of quartiles

	Pb
quartile 1	1.3083
quartile 2	1.7484
quartile 3	2.9333
quartile 4	14.5000

5 contamination levels

- < 1st qu. mean : very low CL
- 1st-2nd qu. mean: low CL
- 2nd-3rd qu. mean: medium CL
- 3rd-4th qu. mean: high CL
- > 4th qu. mean: very high CL

Clustering

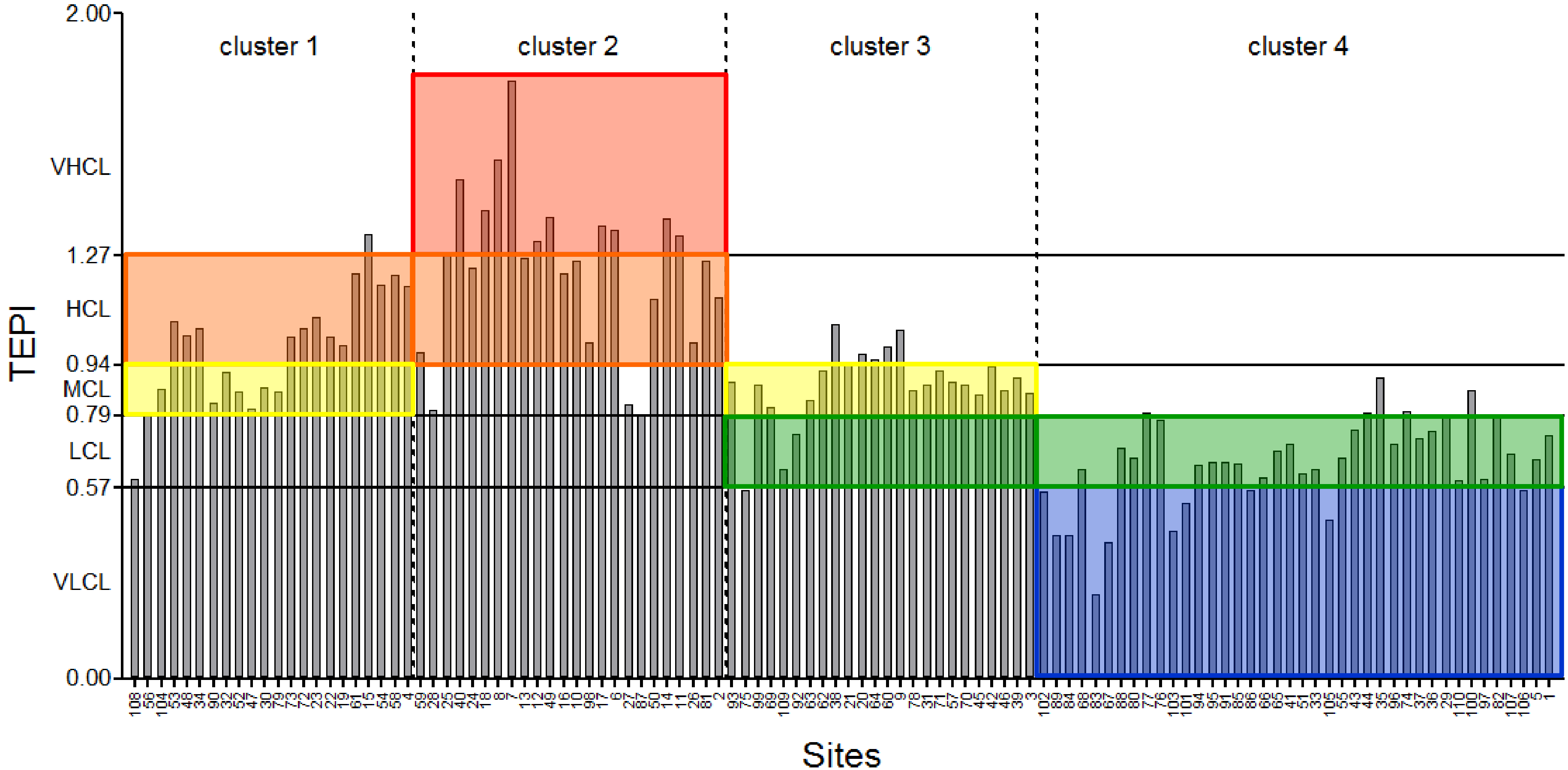

21
18
15
12
9
6
3
0
Linkage distance
Sites
sites highly contaminated
sites little contaminated
cluster 1
cluster 2
cluster 3
cluster 4

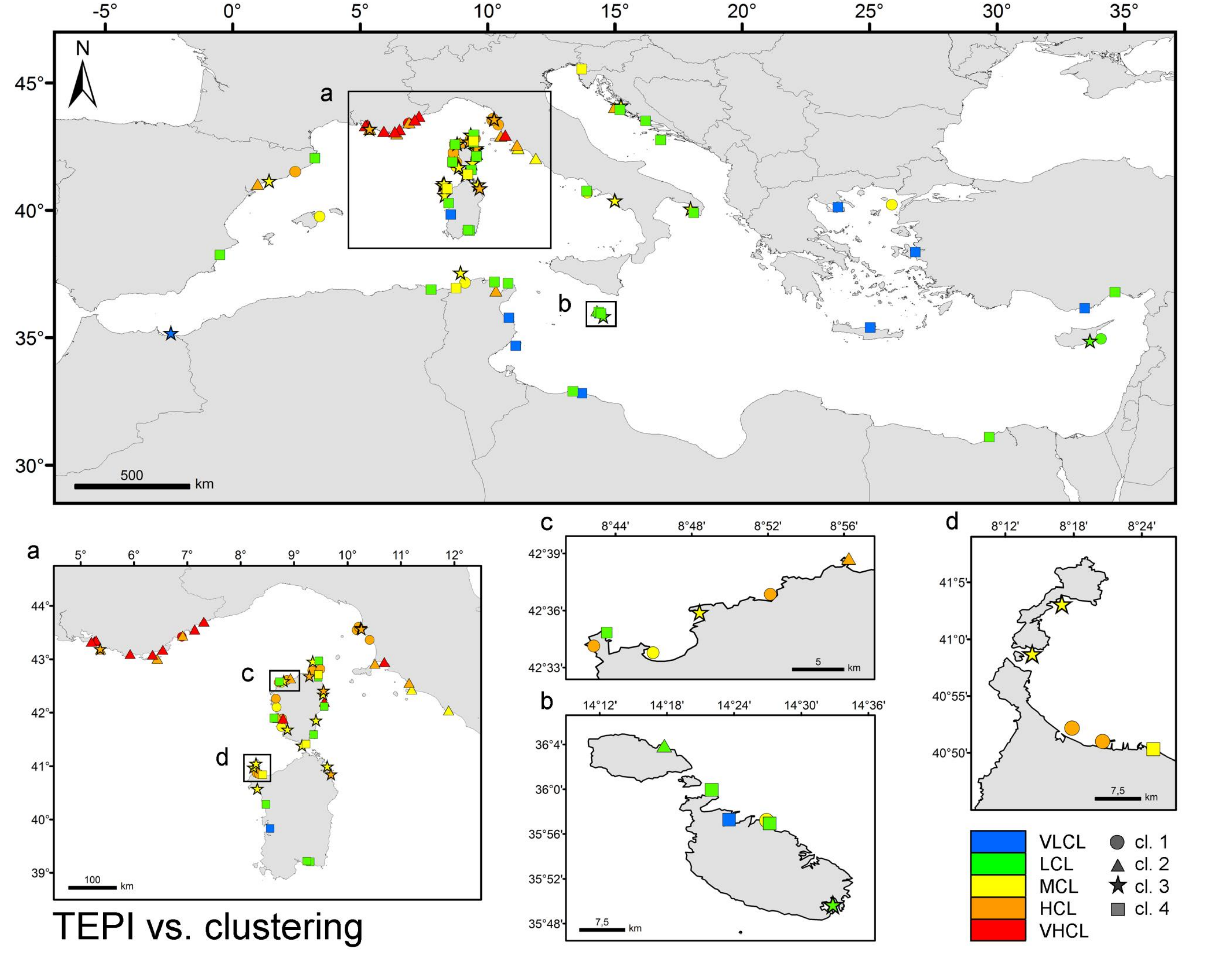
Clustering vs. TEPI

HC by Cd, Ni; LC by As

HC by Ag, As, Pb

LC by TEs overall

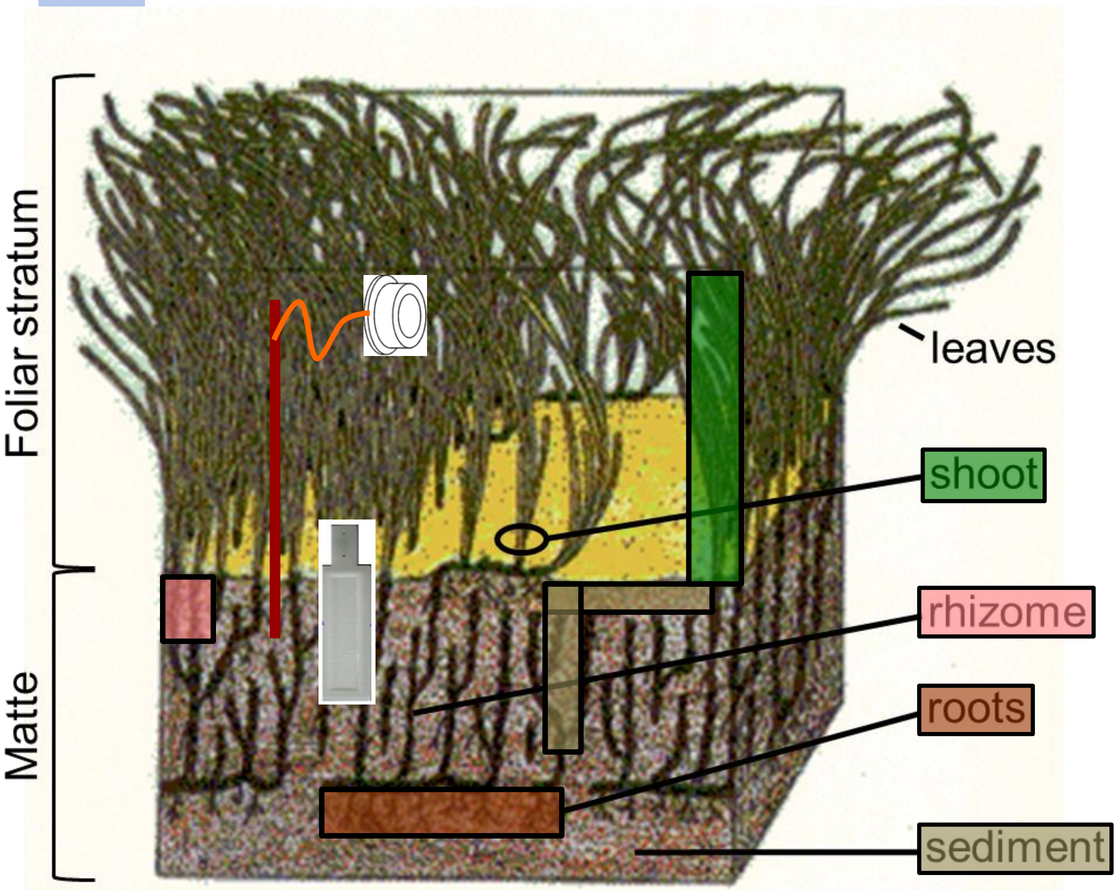




N
a
b
500
km
c
d
100
km
5
km
7,5
km
7,5
km
VLCL
LCL
MCL
HCL
VHCL
cl. 1
cl. 2
cl. 3
cl. 4
TEPI vs. clustering

Posidonia oceanica bed

- *Posidonia oceanica*: shoots, rhizomes and roots;
  - Foliar stratum ◀ water;
  - Matte ◀ sediments.



Seagrass meadow components

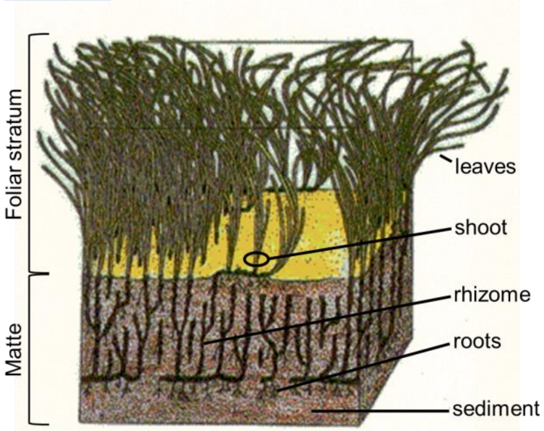
Seagrass meadows can be conceptualized as the juxtaposition of 5 separate components:

- seagrass shoots,
- epiphytes,
- associated algae and animals,
- detritus,

exchanging flows of TEs between themselves and with their environment:

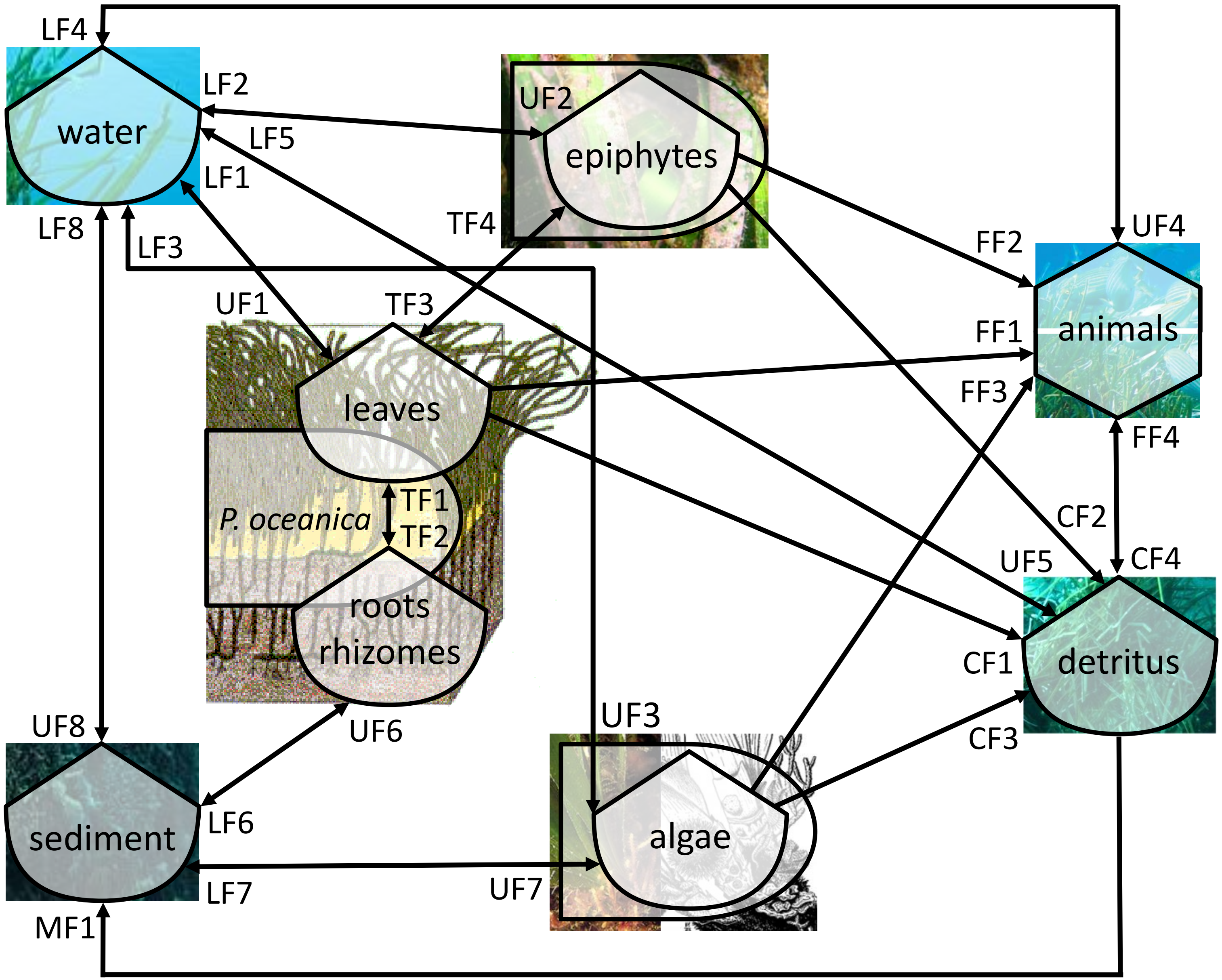
- water,
- sediment.

(Schroeder and Thorhaug, 1980)

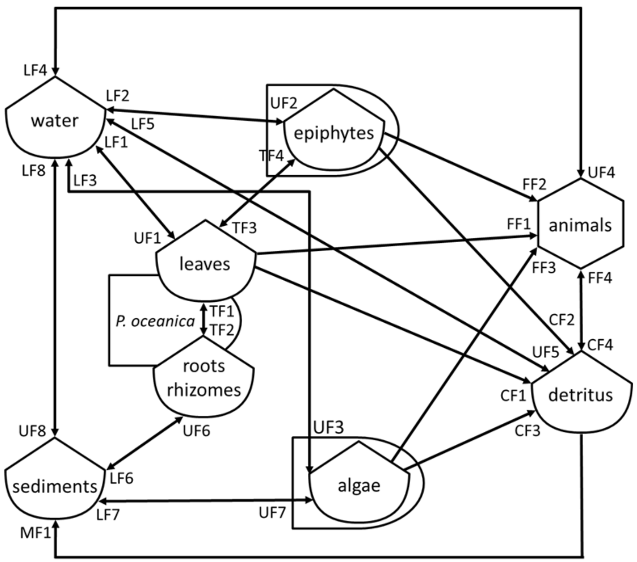


(After Boudouresque and Meinez, 1983)

Diagram in energy circuit language



Flows : experimental design

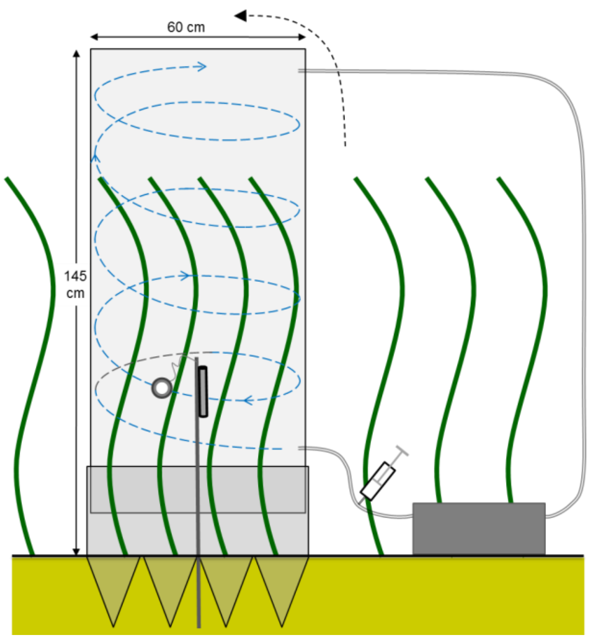


Experimental exposure:

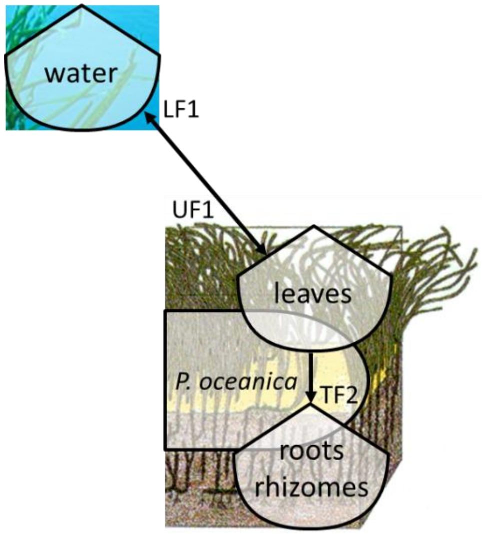
- In aquaria;
- *In situ.*

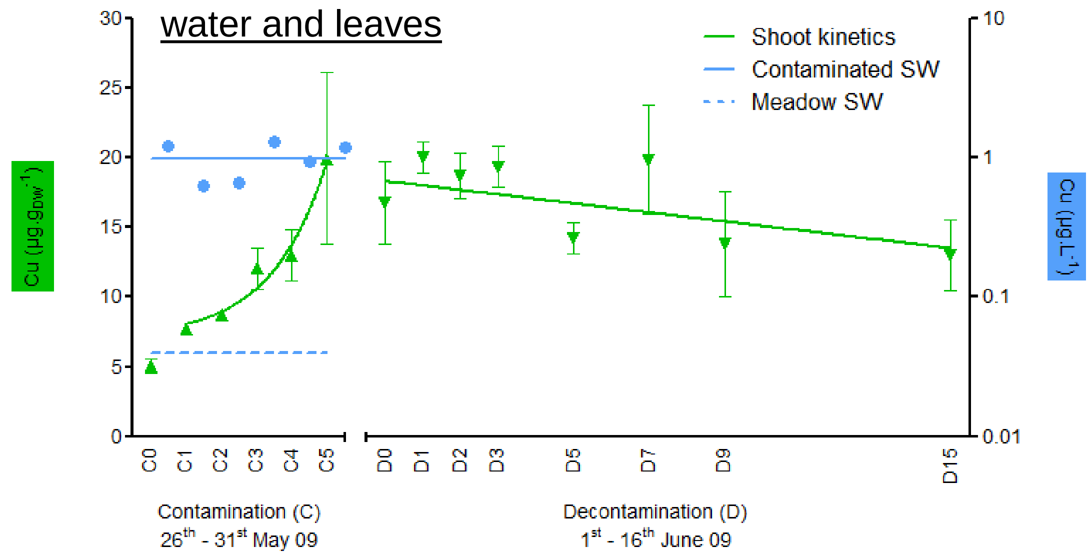
Trace elements:

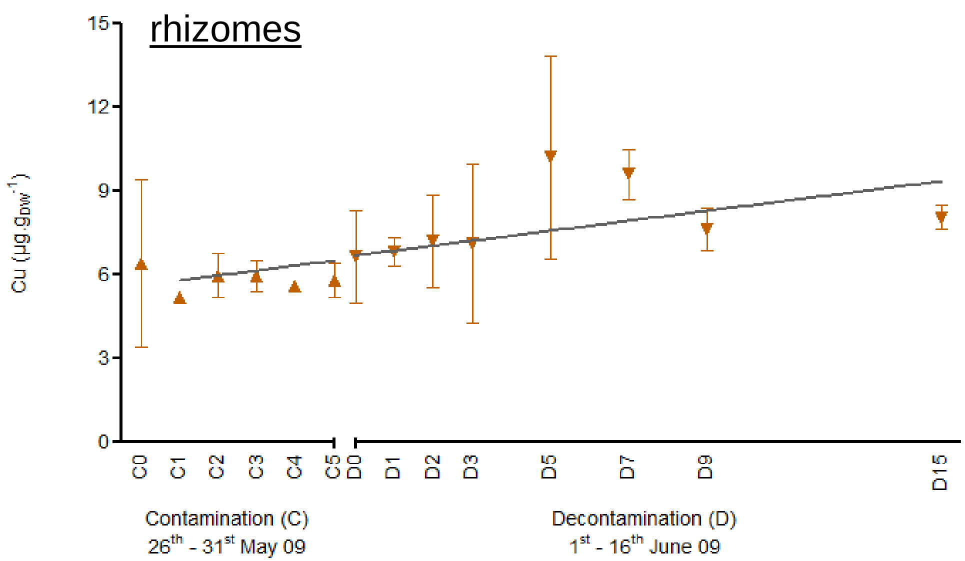
- Contamination with radionuclides;
- Enrichment of the less abundant stable isotopes;
- High relevant concentrations in pristine conditions.

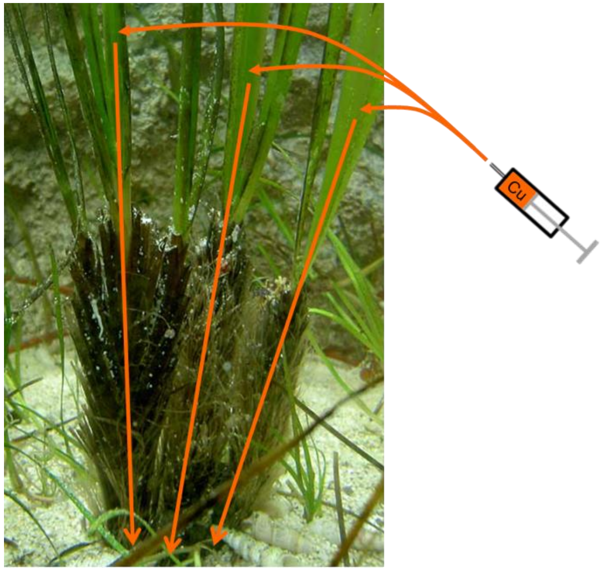


Flows : uptake and translocation





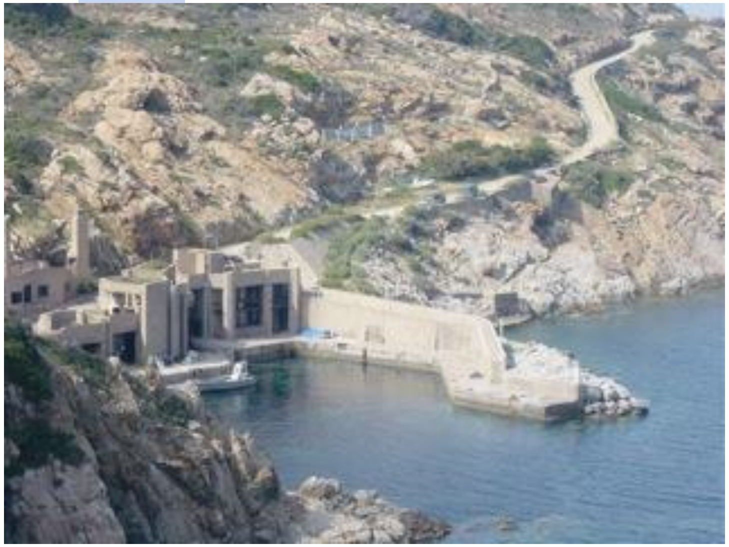


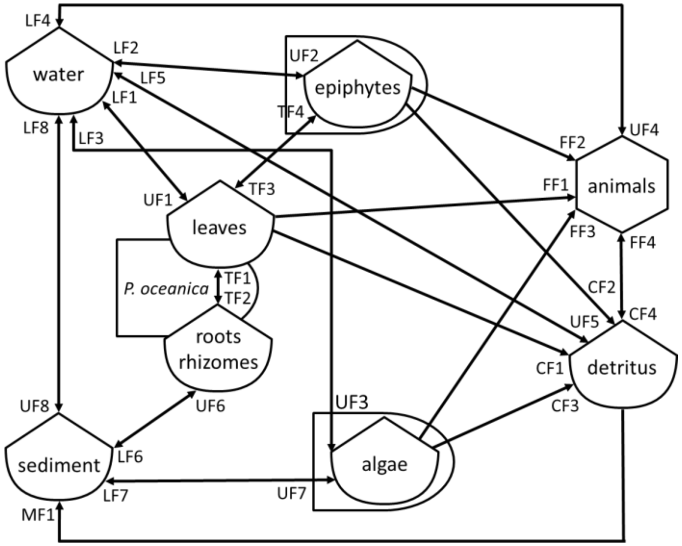


TEs in seagrass meadows

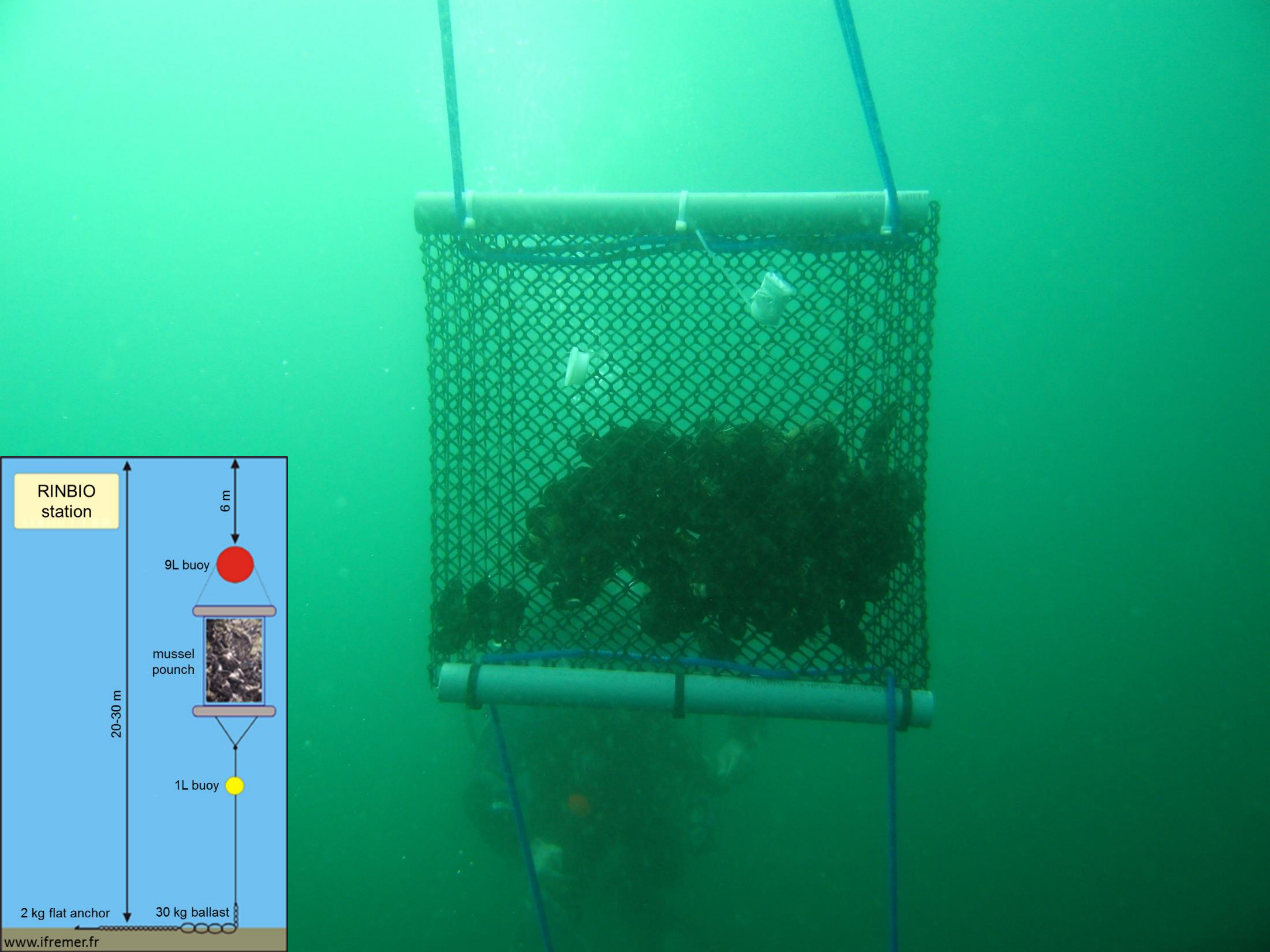
- Data compilation for the different components of the model;
- Mass balance analyses;
- Experiments.

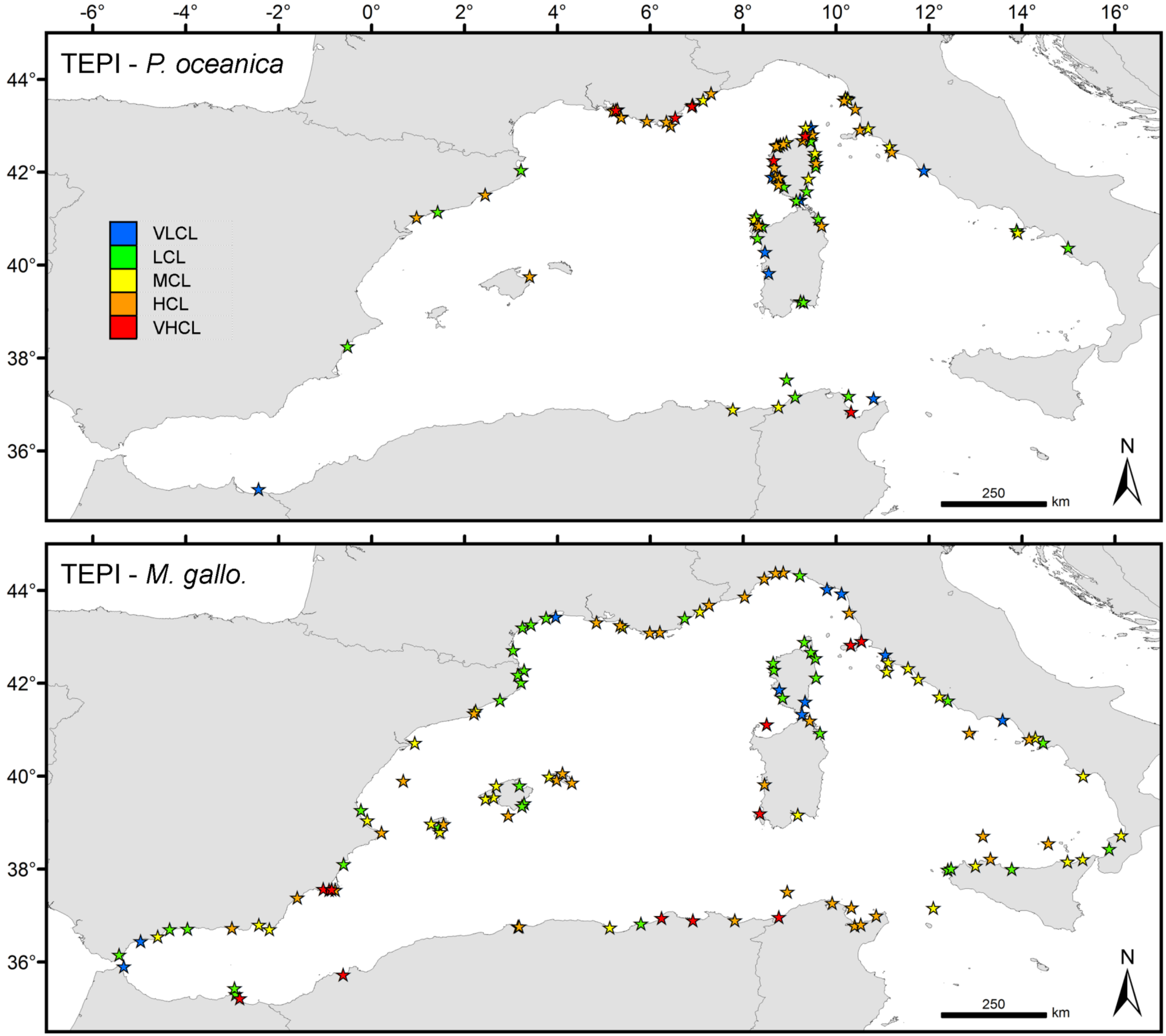
➡ The quantification of the role played by *P. oceanica* meadows in the coastal biogeochemistry of TEs and their function of biological filter.





M. galloprovincialis monitoring station


RINBIO
station
6 m
9L buoy
mussel
pounch
20-30 m
1L buoy
2 kg flat anchor
30 kg ballast
www.ifremer.fr


TEPI - P. oceanica
-6°
-4°
-2°
0°
2°
4°
6°
8°
10°
12°
14°
16°
44°
42°
40°
38°
36°
VLCL
LCL
MCL
HCL
VHCL
N
250
km
TEPI - M. gallo.
44°
42°
40°
38°
36°
N
250
km

Marine Pollution Bulletin 58 (2009) 1389–1400

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ELSEVIER

Integrating long-term water and sediment pollution data, in assessing chemical status within the European Water Framework Directive

Itziar Tueros[a,*], Ángel Borja[a], Joana Larreta[a], J. Germán Rodríguez[a], Victoriano Valencia[a], Esmeralda Millán[b]

[a] AZTI-Tecnalia Foundation, Marine Research Division, Herrera Kaia, Portualdea, s/n, 20110 Pasaia, Spain
[b] Departamento de Química Aplicada (Química Analítica), Facultad de Química, Universidad del País Vasco, Apartado 1072, 20080 San Sebastián, Spain

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ELSEVIER

Spatial distribution of metal accumulation areas on the continental shelf of the Basque Country (Bay of Biscay): A GIS-based approach

CrossMark

Irati Legorburu*, Ibon Galparsoro, Joana Larreta, José Germán Rodríguez, Ángel Borja

AZTI-Tecnalia, Marine Research Division, Herrera Kaia z/g, 20110 Pasaia, Spain

A **corporative** Marine Spatial **Data Infrastructure**, developed in the Marine Research Division of AZTI-Tecnalia

United Kingdom data bases

Environment Agency

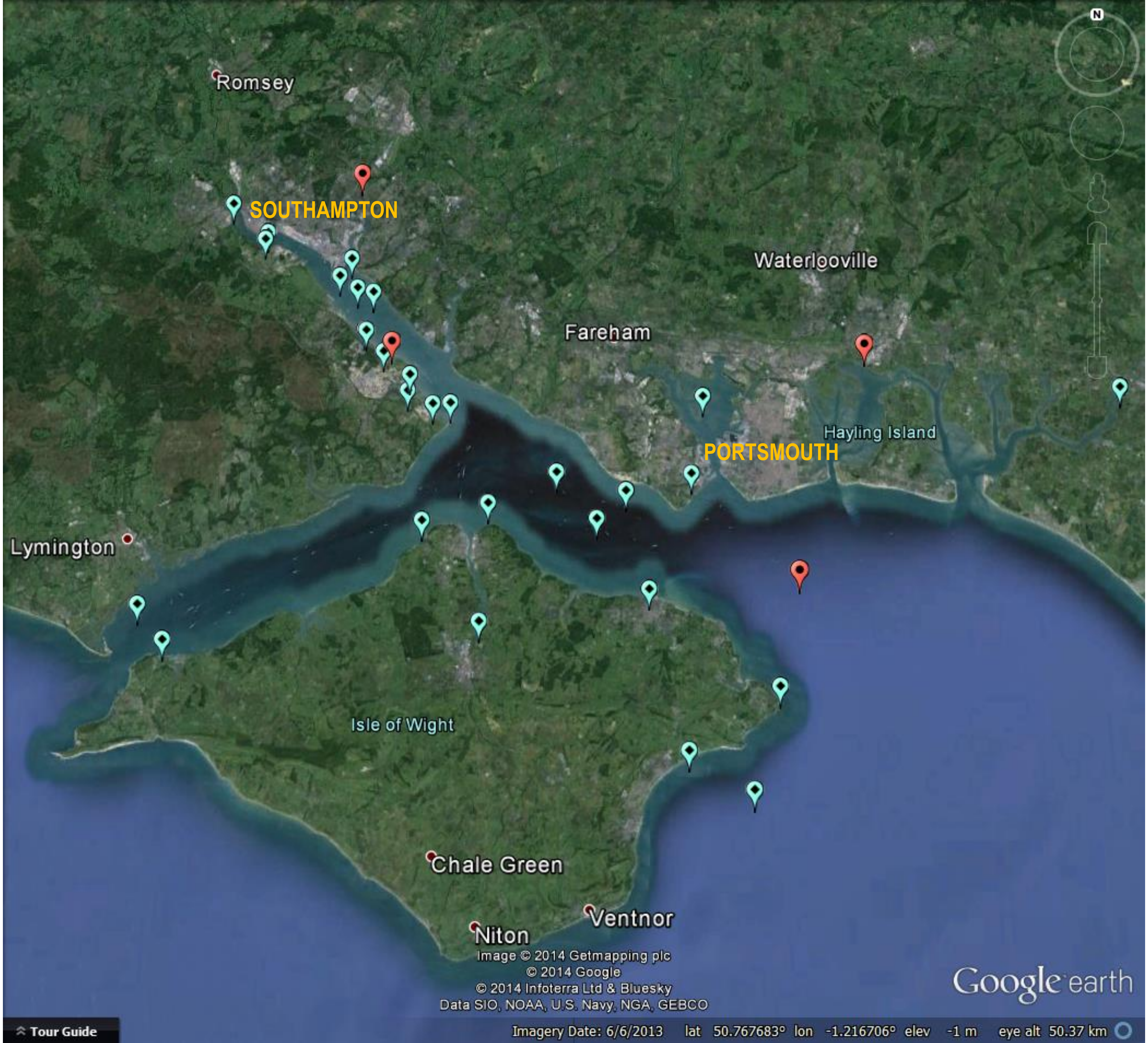
http://www.geostore.com/environment-agency/

“Making environmental information available is key to informing decisions, influencing actions and delivering sustained environmental improvements.”

BODC
British Oceanographic Data Centre
NATURAL ENVIRONMENT RESEARCH COUNCIL

http://www.bodc.ac.uk/projects/uk/merman/

Marine Environment Monitoring and Assessment National database (MERMAN) → a national database which holds and provides access to data collected under the Clean Safe Seas Environmental Monitoring Programme (CSEMP).



Romsey
SOUTHAMPTON
Waterlooville
Fareham
Hayling Island
PORTSMOUTH
Lymington
Isle of Wight
Chale Green
Ventnor
Niton
Image © 2014 Getmapping plc
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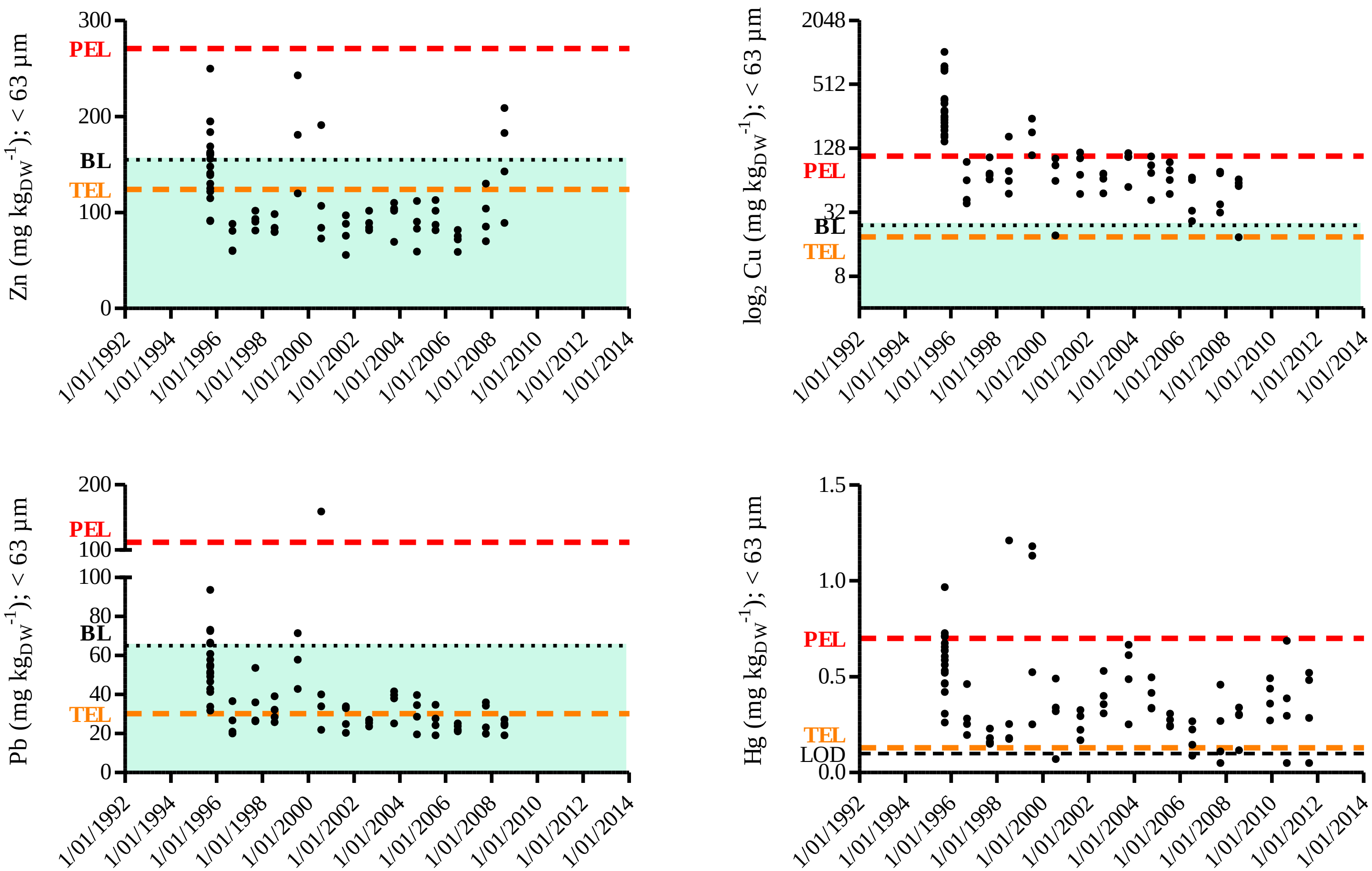
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Google earth
Tour Guide
Imagery Date: 6/6/2013 lat 50.767683° lon -1.216706° elev -1 m eye alt 50.37 km


Hardley
Holbury
Fawley
Image © 2014 Getmapping plc
© 2014 Google
Google earth
Tour Guide
1999
Imagery Date: 1/1/2005 lat 50.840364° lon -1.365537° elev 20 m eye alt 3.18 km

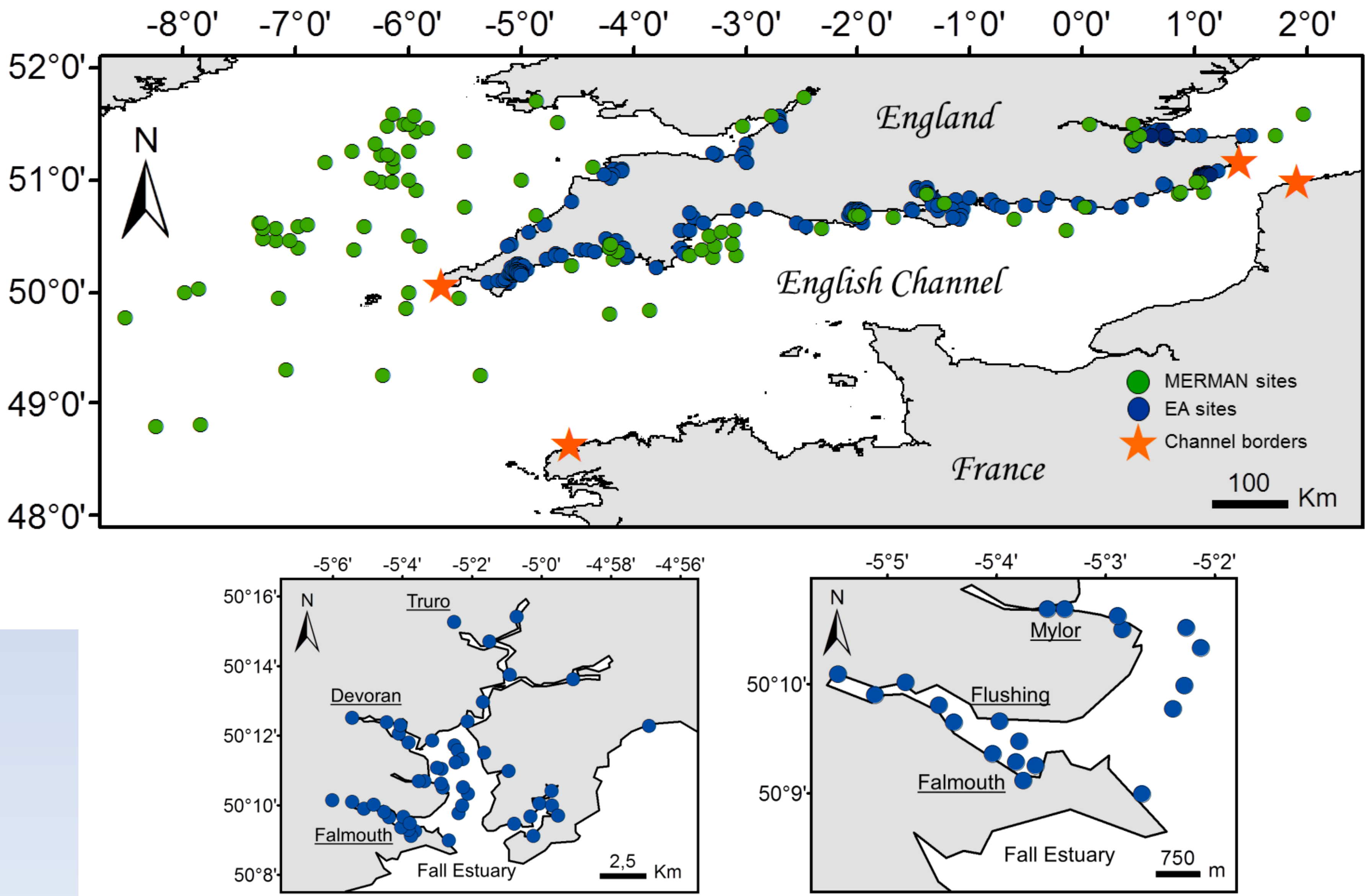
Solent as a case study: oil refinery



Baseline TE levels (BL) (Rainbow et al., 2011);

Canadian Sediment Quality Guidelines for the Protection of Aquatic Life: Threshold Effect Level (TEL) and Probable Effect Level (PEL) (Hübner et al., 2009).

Sediments = environmental archives



Pollution scale

$$EF = C_n / B_n$$

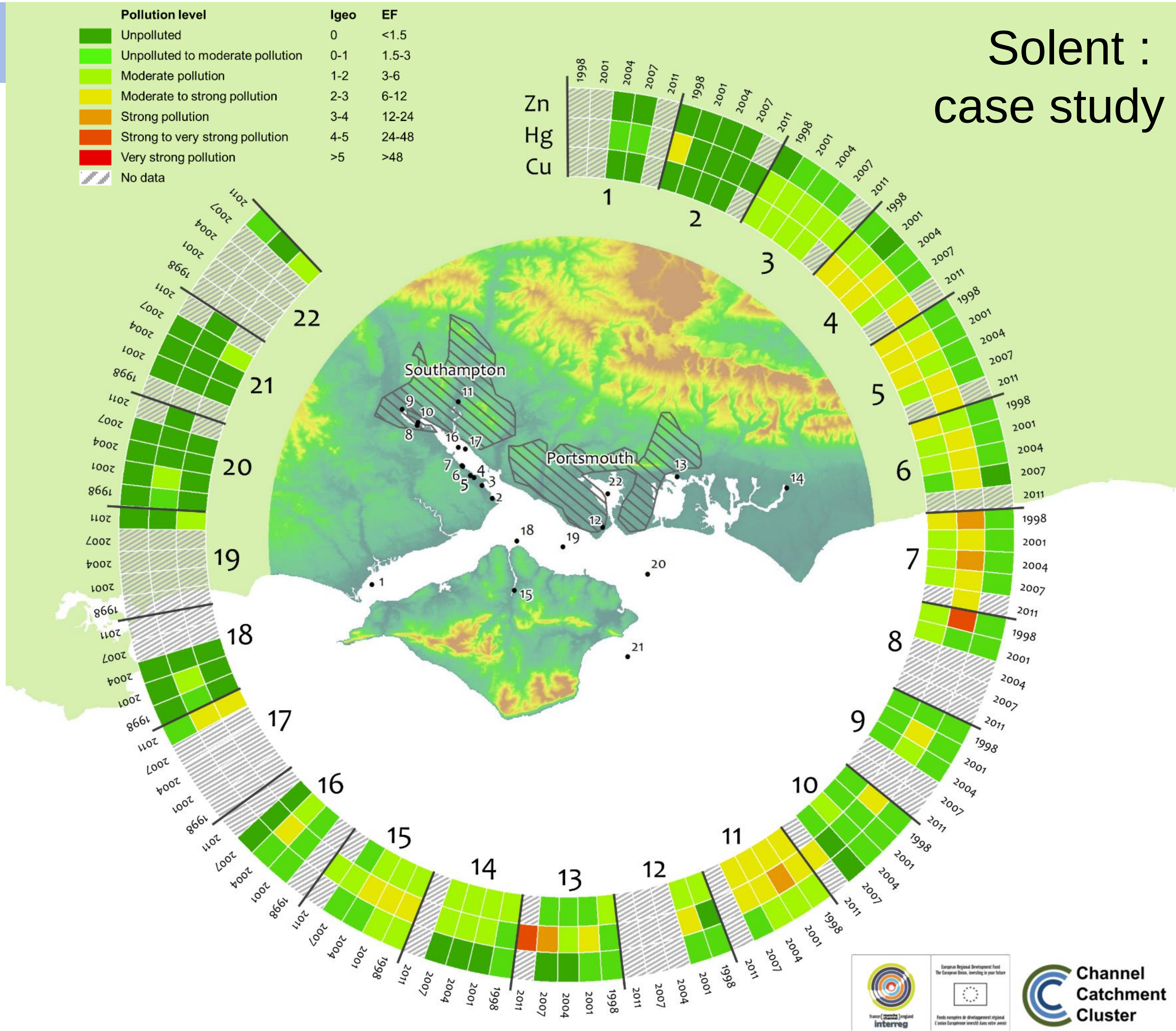
$$I_{geo} = \log_2(EF/1.5)$$

Pollution level	Igeo	EF
Unpolluted	0	< 1.5
Unpolluted – moderate pollution	0–1	1.5 - 3
Moderate pollution	1–2	3 - 6
Moderate – strong pollution	2–3	6 - 12
Strong pollution	3–4	12 - 24
Strong – very strong pollution	4–5	24- 48
Very strong pollution	>5	> 48

Enrichment Factor (EF) of a TE = the ratio between its concentration in the sediment and its natural background concentration (Tomlinson et al., 1980);

Depending upon the Geoaccumulation Index values (I_{geo}), sediments can be classified into 7 classes, according to their level of pollution (Müller, 1979).

Solent : case study

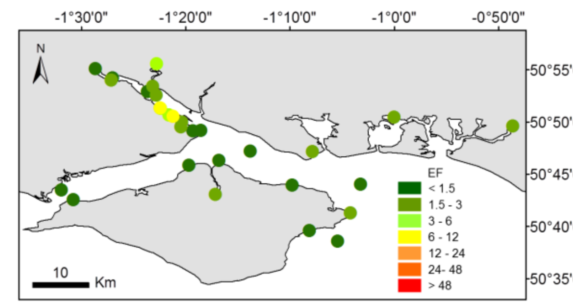


Channel Catchment Cluster

Data mining - Decision tools - Monitoring

- ✓ Long-term sediment pollution data:
  assessment of the chemical
  status within the European WFD;

- ✓ Knowledge transfer from scientists to environmental managers:
  develop practical environmental
  management tools;



- ✓ Complementary monitoring approach:
  environmental compartments
  vs. biota.

Questions?

… Thank you for your attention …