Ulisses

UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

ulisses.ulisboa.pt

unite! University Network for Innovation, Technology and Engineering

U LISBOA | UNIVERSIDADE DE LISBOA

Co-funded by the Erasmus+ Programme of the European Union

Bio-remediation of water: How to remove heavy metals

Isabel Caçador
Plant Department, Faculty of Sciences of the University of Lisbon
MARE - Marine and Environmental Sciences Centre

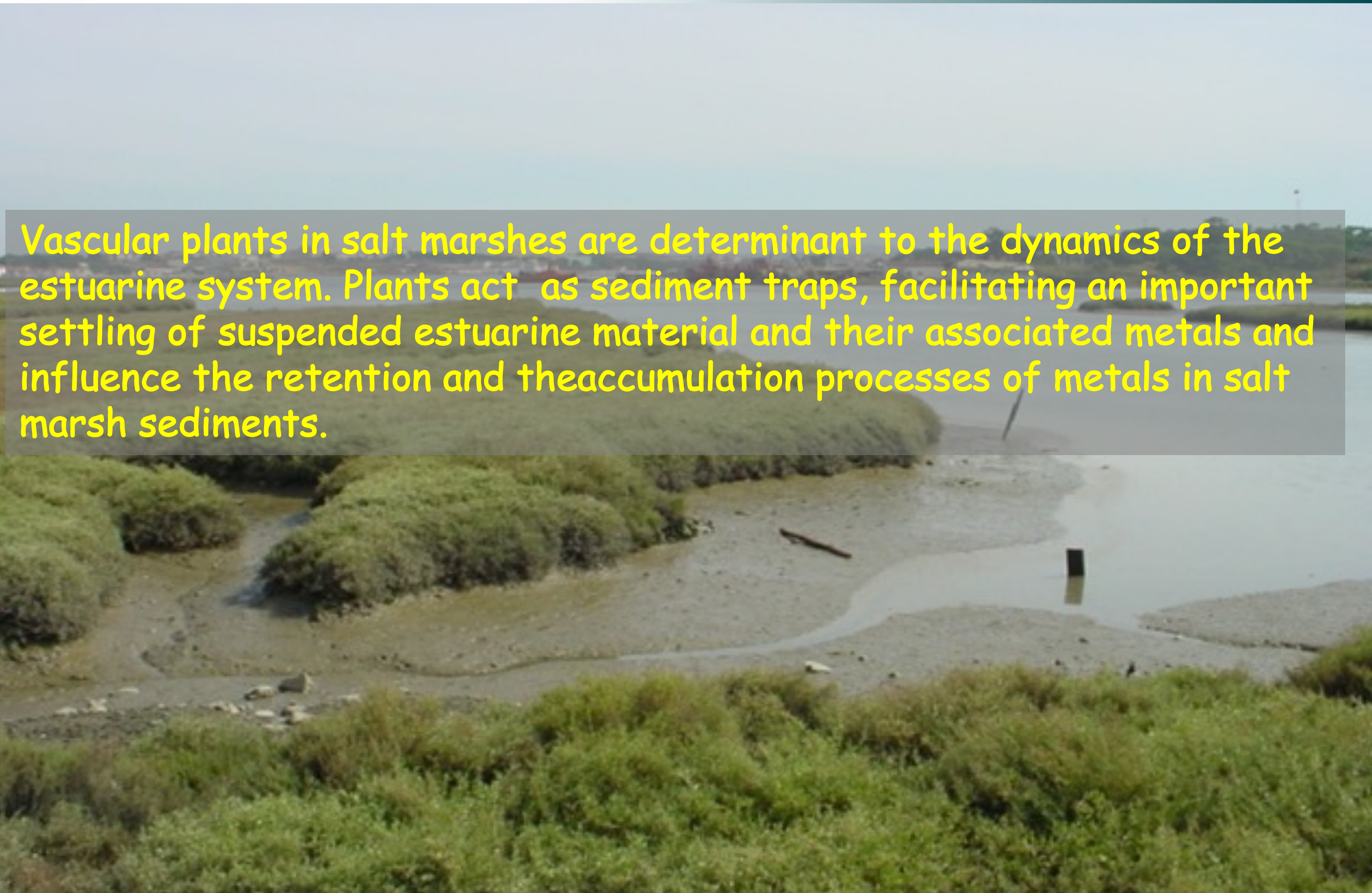
unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

Tagus estuary salt marshes: a case study

unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

Tagus Estuary

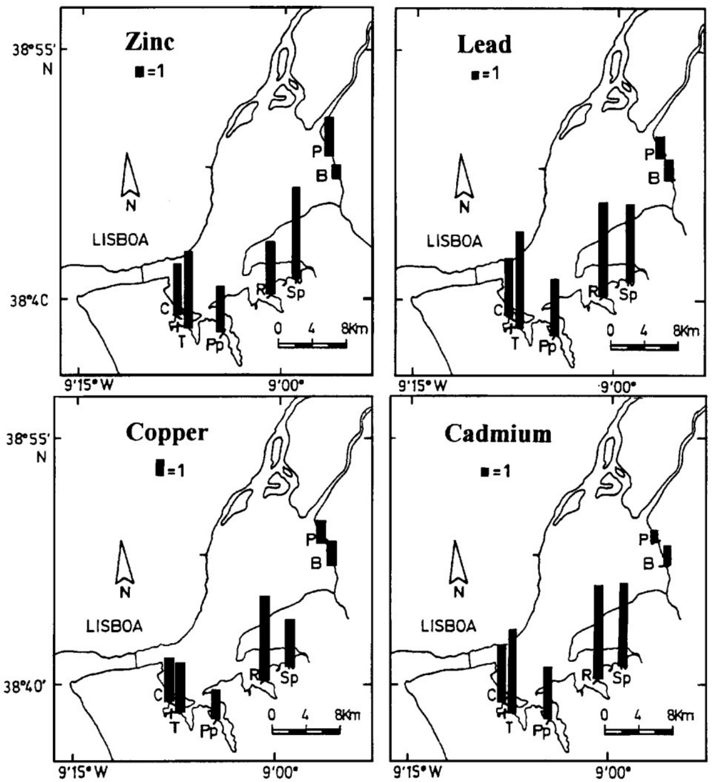
- Located in the western coast of Portugal .
- One of the greatest Estuaries of Europe.
- Highly urbanized.
- Highly industrialized.
- High volume of marine traffic (recreational, fisheries, cargo transport).



Vascular plants in salt marshes are determinant to the dynamics of the estuarine system. Plants act as sediment traps, facilitating an important settling of suspended estuarine material and their associated metals and influence the retention and theaccumulation processes of metals in salt marsh sediments.

unite! University Network for Innovation, Technology and Engineering
ULISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

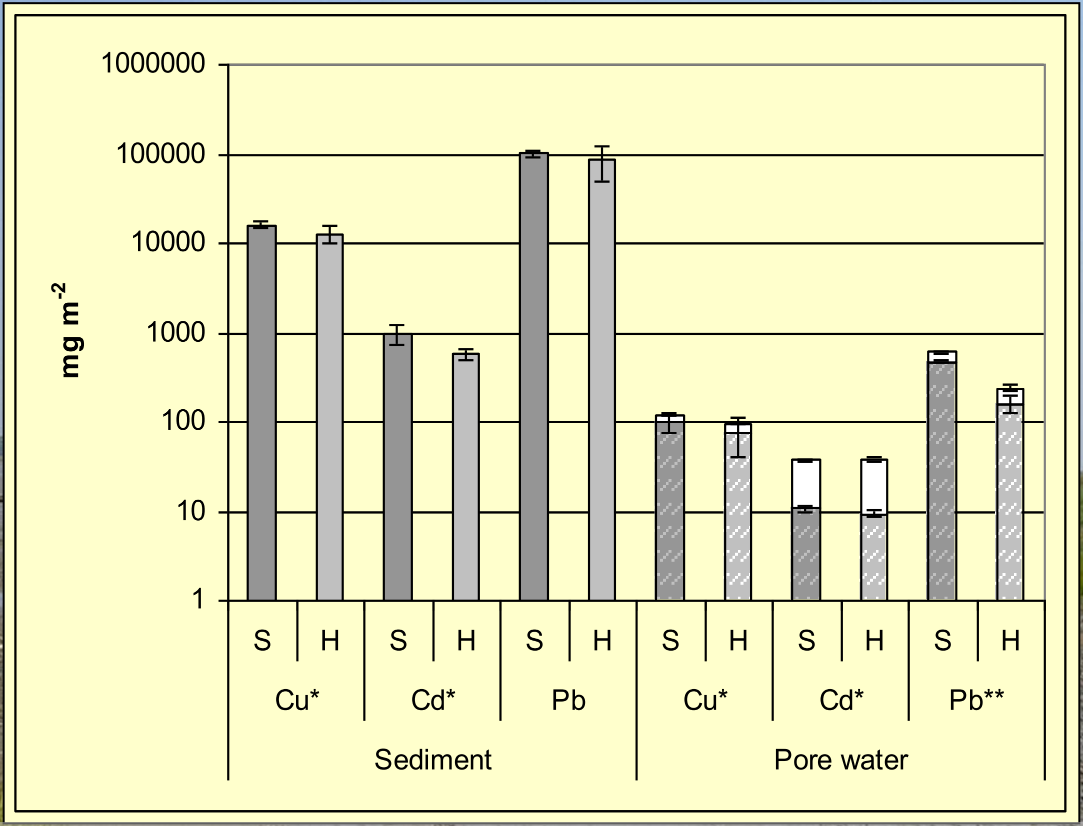
Enrichment Factors of Zinc, Lead, Cooper and Cadmium in Tagus Estuary saltmarshes



EF=Ratio between metal concentration in the upper sediments (0-5 cm) and layers below roots (45-55cm)

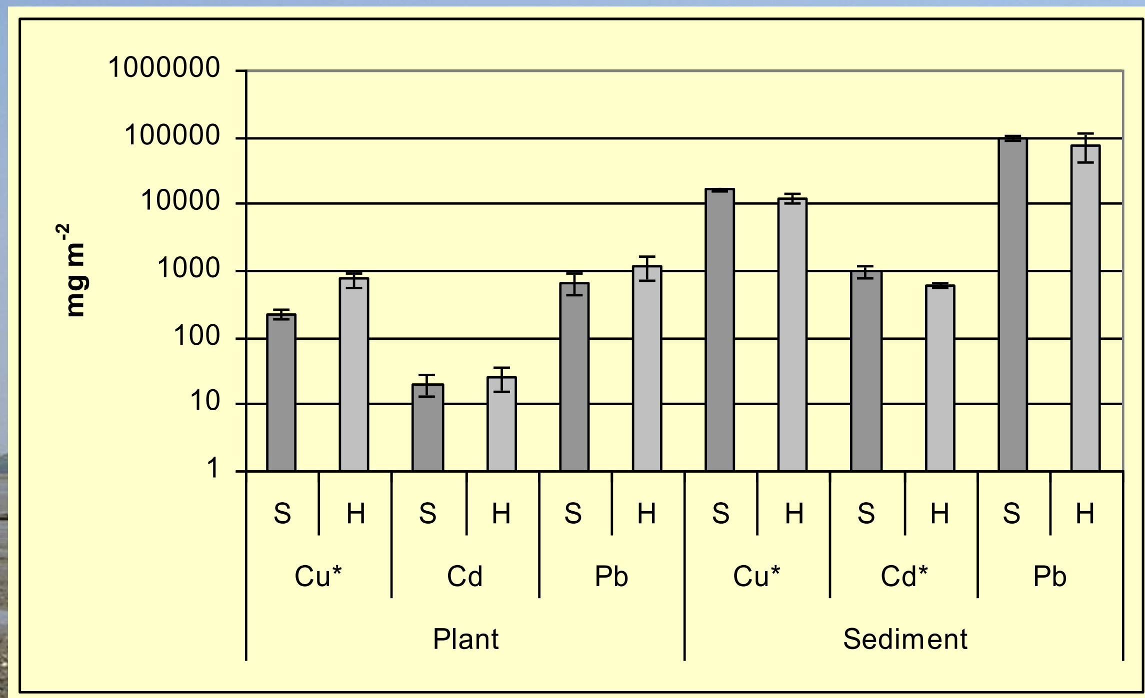
Higher enrichment factors were found close to the anthropogenic sources, highlighting the role of salt marshes in the retention of metals in this system.

Only a small fraction (1%) of heavy metals are in the pore water



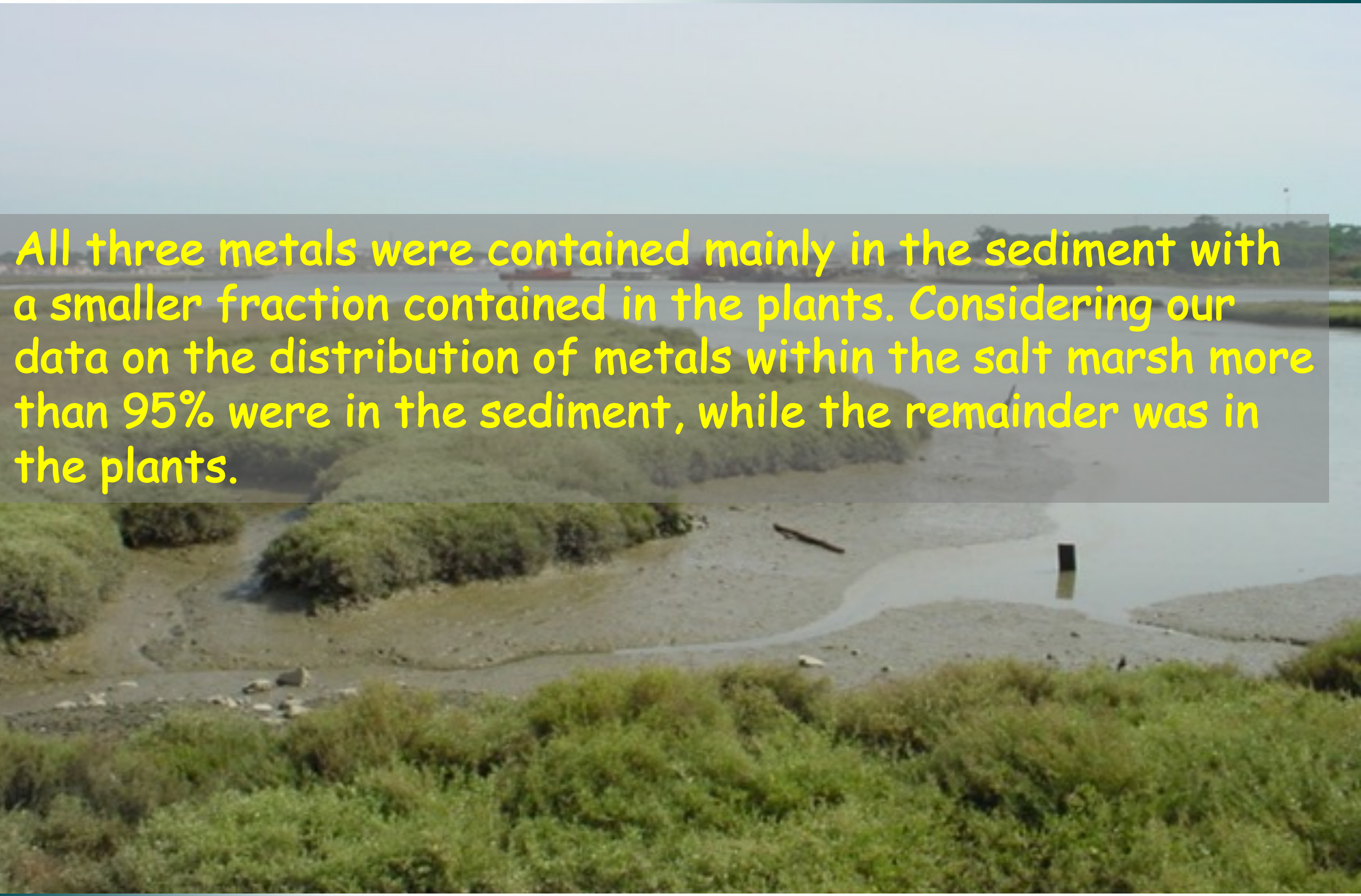
Heavy metal concentrations in sediments and dissolved fraction

The sediment is the main pool of metals



Cu, Cd and Pb content in plants and sediment (mg m-2) in a 40cm-depth layer in areas colonised by *Halimione portulacoides* (H) and *Spartina maritima* (S).

unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union



All three metals were contained mainly in the sediment with a smaller fraction contained in the plants. Considering our data on the distribution of metals within the salt marsh more than 95% were in the sediment, while the remainder was in the plants.

In all plants the root system is the main pool of metals, only a small portion has translocated to the aerial parts. *Sarcocornia fruticosa* and *Halimione portulacoides* acumullate about 7 and 4 thousands mg per square meter of Zinc in the root system, respectively highlighting its phytoextraction capacity by accumulation in plant tissues. By the contrary Sarcocornia perennis and Spartina maritima acumullate only about 2 and 1,5 thousands mg per square meter of Zn respectively, highlighting its capacity in phytostabilisation of metals in rhizosediments. The same pattern was obseved for Pb, Cooper and Cadmium.

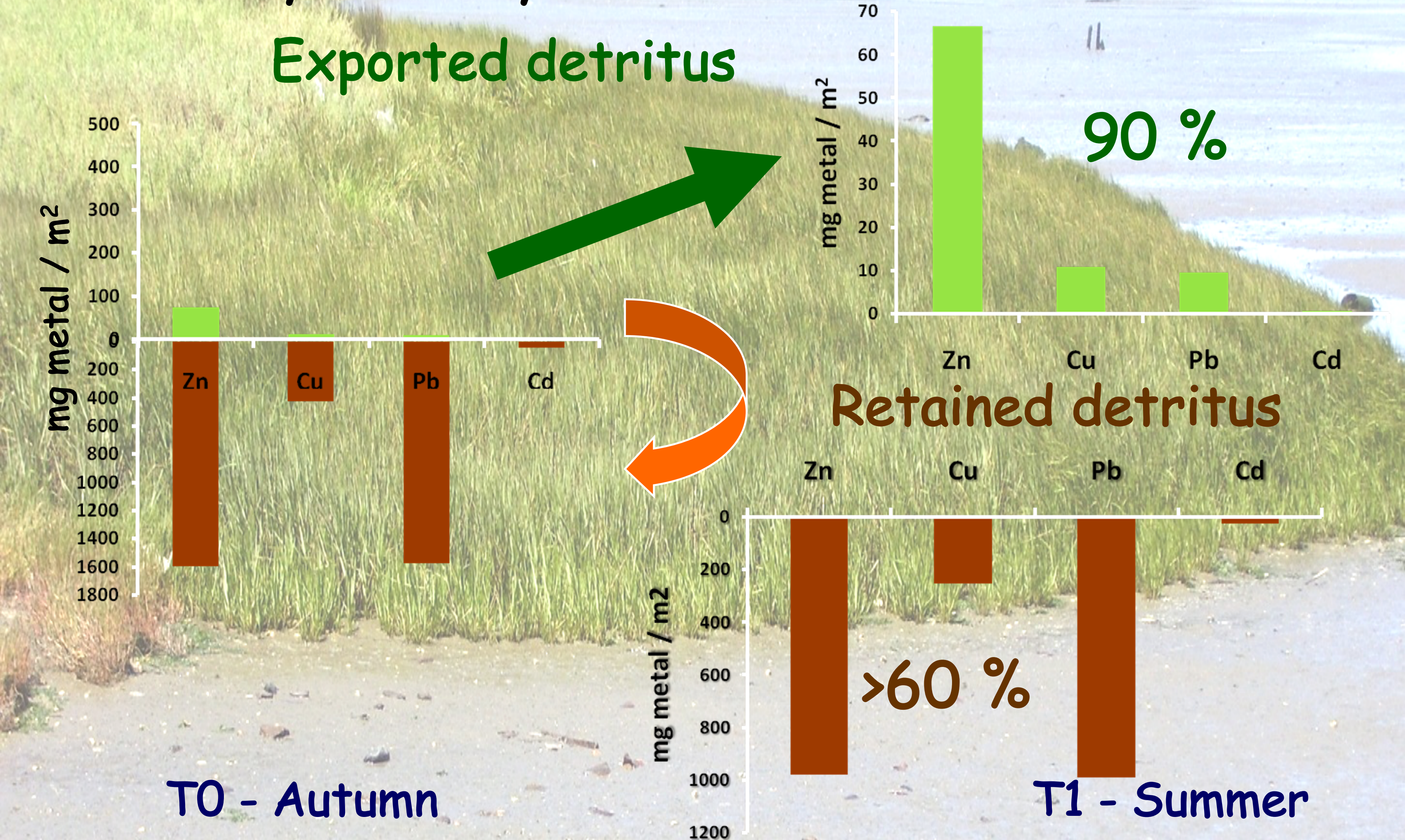
For instances *Halimione* acumullate about 4 thousands mg per square meter in the root system and 35 mg in the stems and 10 mg in the leaves. The amounts acumulated in the aerial parts are almost totaly exported. By the contrary only a small part of the metal retained in the roots are reintroduced in the surrounding environment. Probably some of these metals returned to the sediment bound to the organic matter. Complex interactions between plant roots and sediments may result in the metal redistribution in sediments and retention in iron-rich structures formed around roots.

unite! University Network for Innovation, Technology and Engineering | U LISBOA Universidade de Lisboa | Co-funded by the Erasmus+ Programme of the European Union

Salt marsh plants take up metals from contaminated sediments during the growth season and accumulate them in the plant tissues, mostly within the root system. In this way, vascular plants act as temporary "sinks" for heavy metals. Roots also act as an important vector to the incorporation of metals in salt marsh sediments.

When plants absorb and translocate metals to aboveground tissues, they can act as a conduit for the movement of metals from sediment into the food webs of marshes and near shore waters, after plants die.

Heavy metal dynamics in *S. maritima* marsh



Vegetated litter is the main source of organic matter to salt marshes, as well as an important vehicle of metals that have been uptaken by plants during their growing.

Although 90/ of aboveground detritus is exported to the estuary it represents a small amount of the plants retained metals, because the higher amounts of biomass belongs to the roots system and it is also the more contamineted tissues

Ulisses

Litter from plant species is the main source of organic matter to salt marshes, as well as an important vehicle of metals that have been uptaken by plants during their growing.

Although 90% of aboveground detritus is exported to the estuary it represents a small amount of the plants retained metals, because the higher amounts of biomass belongs to the root system and it is also the more contamineted tissues

unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

Salt marshes are frequently the recipient of great inputs of heavy metals. These heavy metals deposit in the sediment becoming available for plant uptake and entering the food chain.

This will lead to processes of bioaccumulation and Biomagnification, being these metals accumulated in the living tissues.

After dead of the animals, or during senescence of the plant parts the contaminated organic matter is deposited in the sediments becoming available to decomposition.

During this degradation process metals can be released throughout organic matter break down.

unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

The accumulation of heavy metals in the sediments and vegetation,together with the root-sediment interactions, contribute to an overhall reduction of metal bioavailability

These facts suggest that salt marshes in the Tagus estuary may be important areas to help reduce the environmental contamination caused by heavy metals occurring within the estuary

The possible use of these species for phytoremediaton could be applicable from two different perspectives:

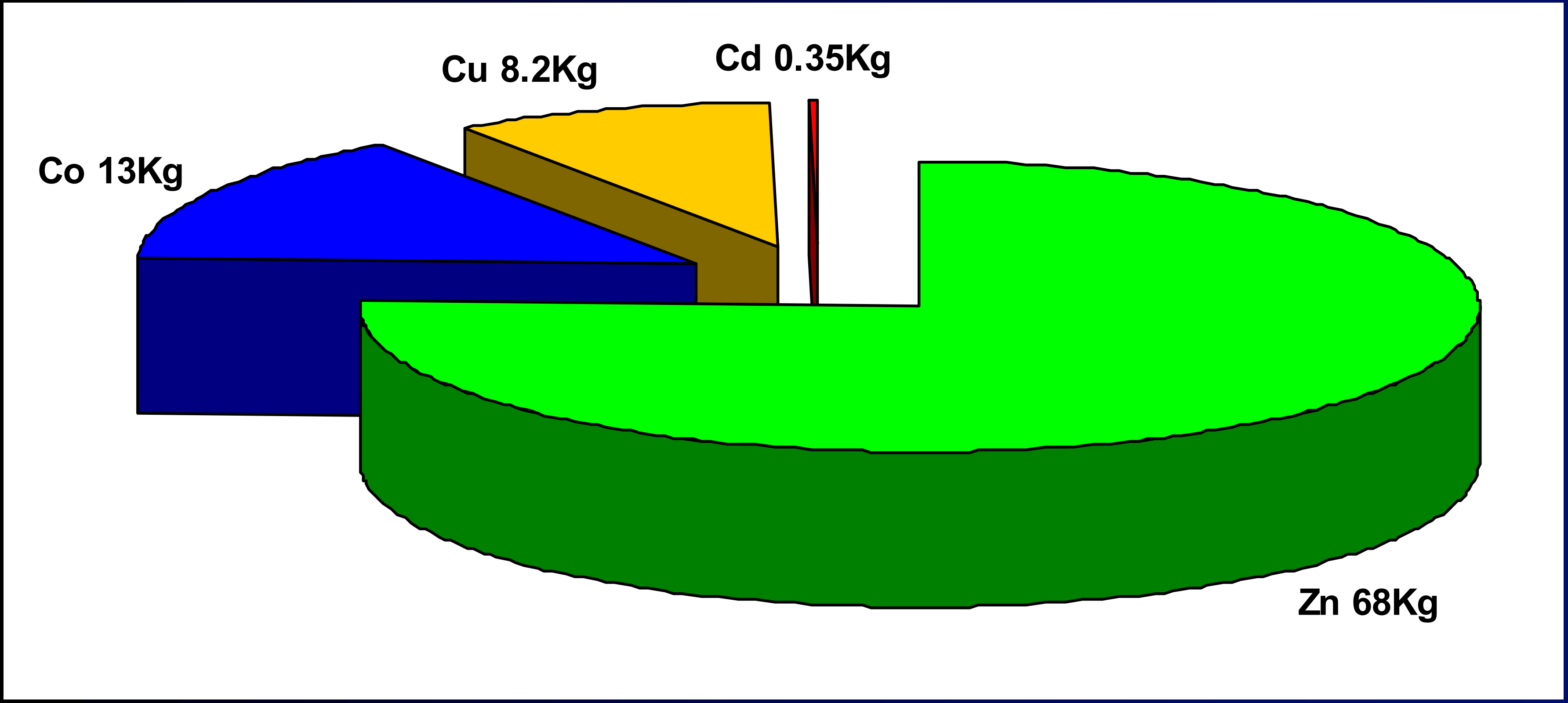
Phytostabilisation of metals in rhizosediments,

or

Phytoextraction by accumulation in aboveground plant tissue for subsequent plant removal.

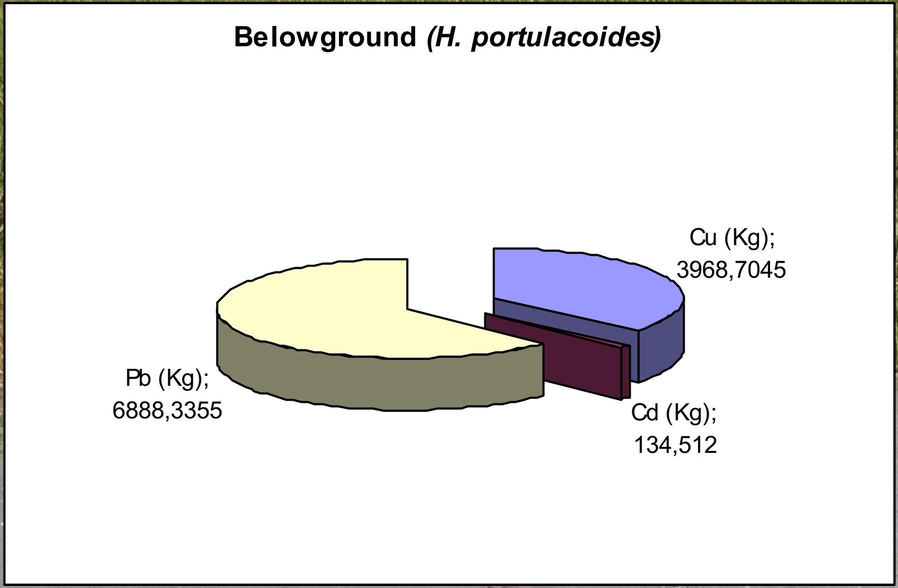
unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

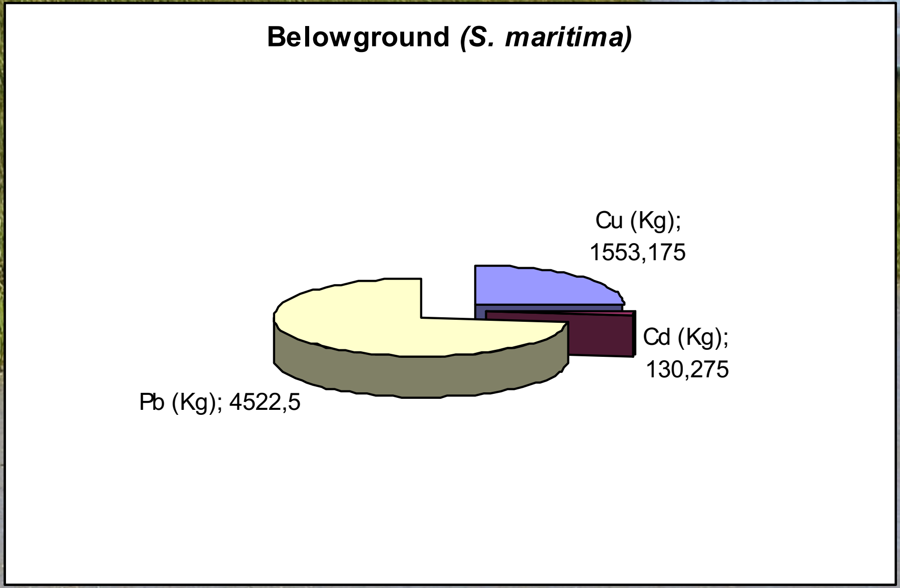
Annual amount of exported metals estimation for Rosário salt marsh (200 ha).



Caçador et al., 2005

Metal retained via root detritus

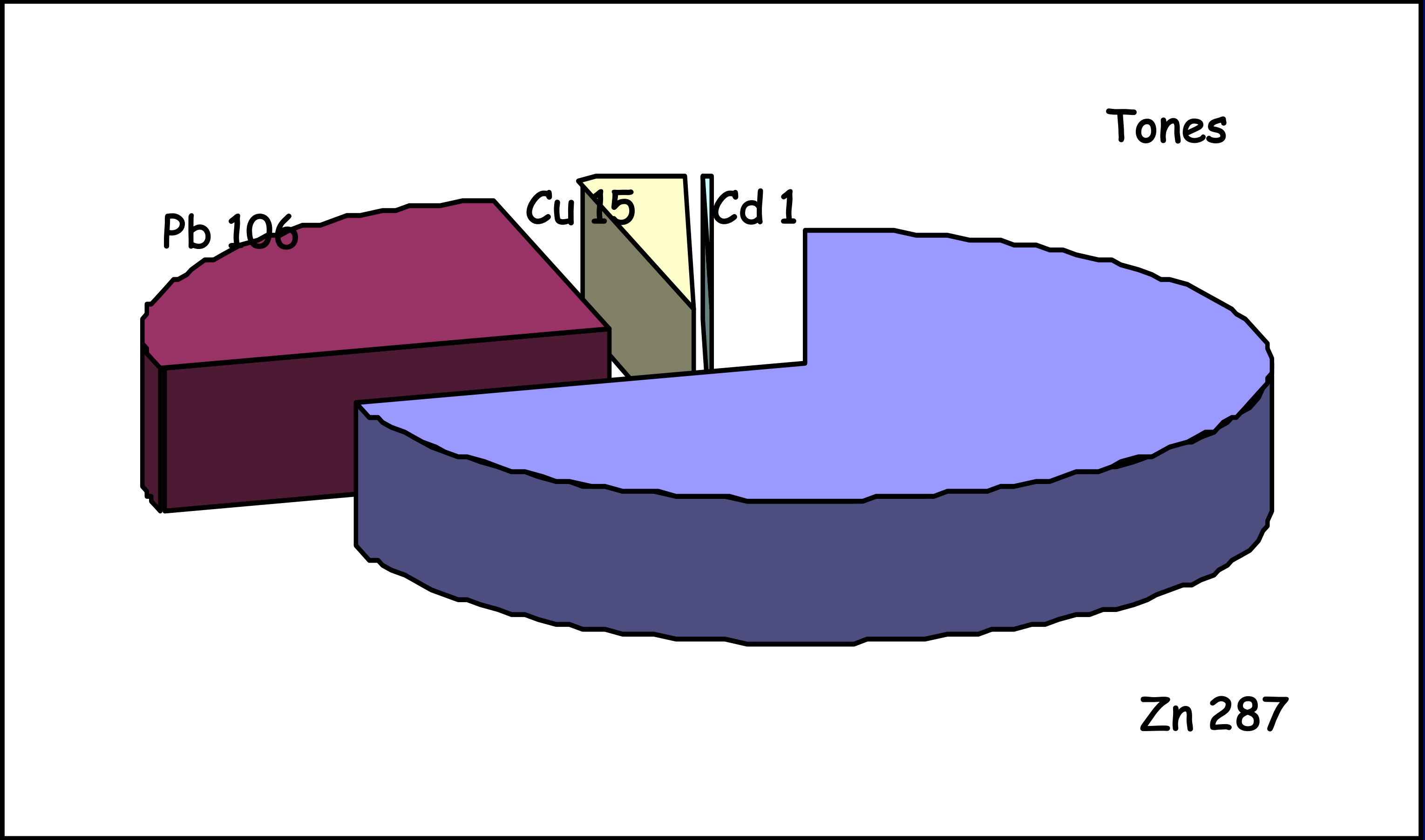




A total of 6888kg of Pb, 134kg of Cd, 3968Kg of Cu were retained in the sediment during a one year period, as organic plant litter in the Rosário salt marsh (200 ha).

unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

Metal retention estimation for Rosário salt marsh (200 ha), in the last 40 years.



Some Final Remarks

Several studies have invoked the remediation ability of salt marshes, assuming that metals are greatly immobilised in roots and sediments.

Therefore, to assess the remediation potential in a contamined marsh one should take into account the balance between retention and export of metals from the marsh, the plant species living there and a good undestanding of the marsh ecology.

unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

In conclusion:

Salt marshes have been considered as one of the most important ecosystems, in which concerns carbon harvesting and metal retention.

In fact, this is true although its halophytic composition and metabolic diversity are important shaping drivers of this ecosystem service. Nevertheless salt marsh vegetation constitutes alongside with its sediments a major carbon sink, with a high importance not only for the estuarine carbon balances but also for the world budget.

With high productivities also come high senescence rates, providing to the adjacent water bodies the necessary fuel for secondary production.

In a planet under climate change, all these paradigms need to be re-evaluated. Sea level rise, global warming and atmospheric CO_2 rising will affect not only the halophytes, but all the marsh ecosystem. Nevertheless these ecosystems seem to present an ecosystemic feedback as counteractive measures to climate change, increasing their carbon sinks under climate change.

This reinforces the marshes and in particular the halophytes as key player of the biogeochemical carbon cycle, both at local and global scale

unite! University Network for Innovation, Technology and Engineering
U LISBOA UNIVERSIDADE DE LISBOA
Co-funded by the Erasmus+ Programme of the European Union

References

Lopes C.L., Mendes R., Caçador I. and Dias J.M., 2019. Evaluation of long-term estuarine vegetation changes through Landsat imagery. Science of the Total Environment, 653, 512-522. (DOI: 10.1016/j.scitotenv.2018.10.381.

Brito, P., Prego, R., Mil-Homens, M., Caçador, I. and Caetano, M. 2018. Sources and distribution of yttrium and rare earth elements in surface sediments from Tagus estuary, Portugal. Science of the Total Environment 621, 317-325. (DOI: doi: 10.1016/j.scitotenv.2017.11.245.

Duarte, B., Carreiras, J., Pérez-Romero, J.A., Mateos-Naranjo, E., Redondo-Gómez, S., Maques, J.C. and Caçador, I., 2018. Halophyte fatty acids as biomarkers of anthropogenic-driven contamination in Mediterranean marshes: Sentinel species survey and development of an integrated biomarker response (IBR) index. Ecological Indicators 87, 86-96 (DOI: 10.1016

Duarte, B., Vaz, N., Valentim, J.M., Dias, J.M., Silva, H., Marques, J.C. and Caçador, I., 2017. Revisiting the Outwelling Hypothesis: Modelling Salt Marsh Detrital Metal Exports under Extreme Climatic Events. Marine Chemistry 191, 24-33 (DOI: 10.1016/j.marchem.2016.12.002

Pedro, S., Duarte, B., Almeida, P.R. and Caçador, I. 2015. Metal speciation in salt marsh sediments: influence of halophyte vegetation in salt marshes with different morphology. Estuarine Coastal and Shelf Science 167, 248-255 (DOI: 10.1016/j.ecss.2015.05.034.

Duarte, B., Silva, G., Costa, J.L., Medeiros, J.P., Azeda, C., Sá, E., Metelo, I., Costa, M.J. and Caçador, I., 2014. Heavy metal distribution and partitioning in the vicinity of the discharge areas of Lisbon drainage basins (Tagus Estuary, Portugal). Journal of Sea Research. (DOI: 10.1016/j.seares.2014.01.003

Couto, T., Duarte, B., Barroso, D., Caçador, I. and Marques, J.C. 2013. Halophytes as sources of metals in estuarine systems with low levels of contamination. Functional Plant Biology. 40, 9: 931 – 939. (DOI: 10.1071/FP12300,

Duarte, B. and Caçador, I., 2012. Particulate metal distribution in Tagus Estuary (Portugal), during a flood episode. Marine Pollution Bulletin. 64, 10: 2109-2116. (DOI: 10.1016/

Duarte, B., Caetano, M., Almeida, P. Vale, C. and Caçador, I., 2010. Accumulation and biological cycling of heavy metal in the root-sediment system of four salt marsh species, from Tagus estuary (Portugal). Enviromental Pollution. 158: 1661-1668. (DOI: 10.1016/j.envpol.2009.12.004.

Caçador, I., Caetano, M. Duarte, B. and Vale, C., 2009. Stock and losses of trace metals from salt marsh plants. Marine Environmental Research 67 (2) 75-82. (DOI: 10.1016/j.marenvres. 2008.11.004.

Duarte, B., Almeida, P. R. and Caçador, I., 2009. Spartina maritima (cordgrass) rhizosediment extracellular enzimatic acitivity ans its role in organic matter decomposition processes and metal speciation. Marine Ecology. 30 Suppl.1) 65-73. (DOI: 10.1111/j.1439-0485.2009.00326.x.

Salgueiro, N. & I. Caçador, 2007. Short-term sedimentation in Tagus estuary, Portugal:the I nfluence of salt marsh plants. Hydrobiologia 587:185-193.

Reboreda, R. & I. Caçador, 2007. Halophyte vegetation influences in salt marsh retention capacity for heavy metals. Environmental Pollution 146:147-154.

Caçador, I., Vale, C. and Catarino, F., 2000. Seasonal variation of Zn, Pb, Cu and Cd concentrations in the root-sediment system of Spartina maritima and Halimione portulacoides from Tagus estuary salt marshes. Marine Environemntal Research 49:279-290. (DOI: 10.1016/s0141-1136(99)00077-x

Sundby, B., C. Vale, I. Caçador, F. Catarino, M.J. Madureira & M. Caetano, 1998. Metal-rich concretions on the roots of salt marsh plants: Mechanism and rate of formation. *Limnology and Oceanography* 43 (2):245-252.

Caçador, I., Vale, C. and Catarino, F.M., 1996. The influence of plants on concentration and fractionation of Zn, Pb, and Cu in salt marsh sediments (Tagus Estuary, Portugal). Journal of Aquatic Ecosystem Health 5:193-8.

Caçador, I., Vale, C. and Catarino, F.M., 1996. Accumulation of Zn, Pb, Cu, Cr and Ni in Sediments Between Roots of the Tagus Estuary Salt Marshes, Portugal. Estuarine, Coastal and Shelf Science 42:393-403. IF:


Thank you very much for your attention