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UNIVERSITY OF LISBON
INTERDISCIPLINARY STUDIES
ON SUSTAINABLE ENVIRONMENT AND SEAS

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Bio-remediation of water: How to remove heavy metals

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Topics

1. Salt marshes : definition and characterization
2. Salt marshes and metal retention
3. The halophyte influences on metal availability
4. The influence of halophytes in metal cycling
5. The influence of halophytes in carbon retention

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What is exactly a salt marsh?

The Oxford English Dictionary defines salt marsh as "marshland over washed by the sea"

- More complete definition reflecting the biological and physical attributes of salt marsh would be areas of alluvial or peat deposits, colonized by herbaceous and small shrubby terrestrial vascular plants, almost permanently wet and frequently inundated with saline waters

Where are salt marshes located?

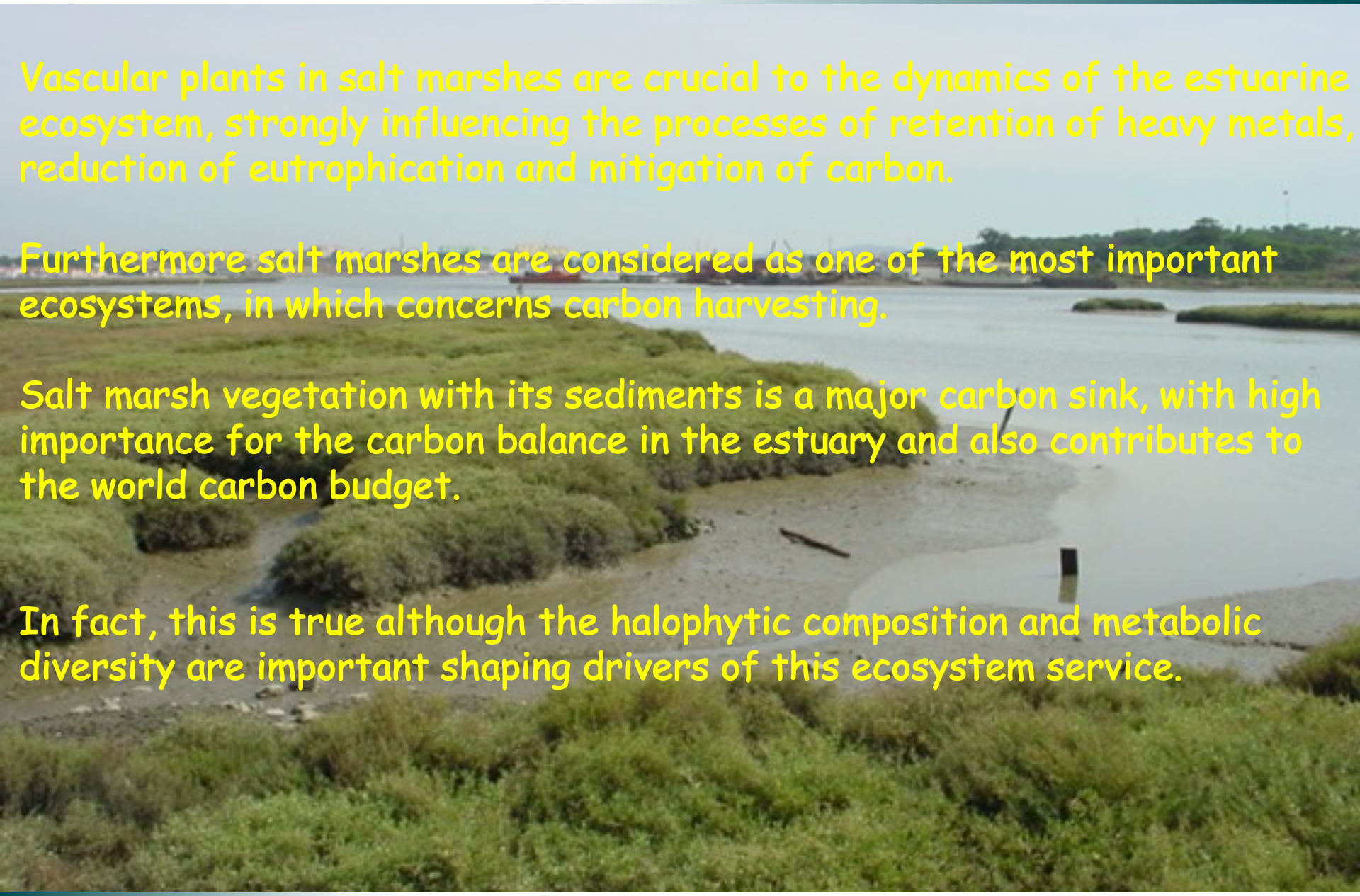
-Salt marshes are transitional areas between land and water, occurring along the intertidal shore of estuaries and sounds where salinity (salt content) ranges from near ocean strength to near fresh in upriver marshes.

What are their features?

Salt marshes are among the most productive ecosystems on the world and perform important ecosystem functions, namely in terms of primary production, nutrient recycling and filtering of natural and anthropogenic loads of nutrients and pollutants. These áreas have a great ecological value for the ecosystem, namely as habitat for fish and birds as well as other wildlife, and shoreline stabilizers.

Vascular plants in salt marshes are determinant to the dynamics of the estuarine ecosystem and strongly influence the processes of accumulation and retention of heavy metals there.

The utilisation of wetlands as filters has gained great interest in the past decades.



Vascular plants in salt marshes are crucial to the dynamics of the estuarine ecosystem, strongly influencing the processes of retention of heavy metals, reduction of eutrophication and mitigation of carbon.

Furthermore salt marshes are considered as one of the most important ecosystems, in which concerns carbon harvesting.

Salt marsh vegetation with its sediments is a major carbon sink, with high importance for the carbon balance in the estuary and also contributes to the world carbon budget.

In fact, this is true although the halophytic composition and metabolic diversity are important shaping drivers of this ecosystem service.

How are they formed?
In moderate to low energy intertidal zones some pionner species can settle and iniciate the colonization of the mudflat.
They promote the sedimentation and enrich the sediment in organic matter. Afterwards other more competitive species arrive. Some islands formed in this way. The saltmarsh grows by the gathering of this small ilands

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How did salt marshes appear?

Hydrology

Hydrology is the main factor in the establishement of the salt marsh and determines the salt marsh characteristics.

The hydrology of a salt marsh influences its physicochemical environment, particularly, oxygen availability and production of hydrogen sulfide.

Hydrology also transports sediments, nutrients, and toxic materials.

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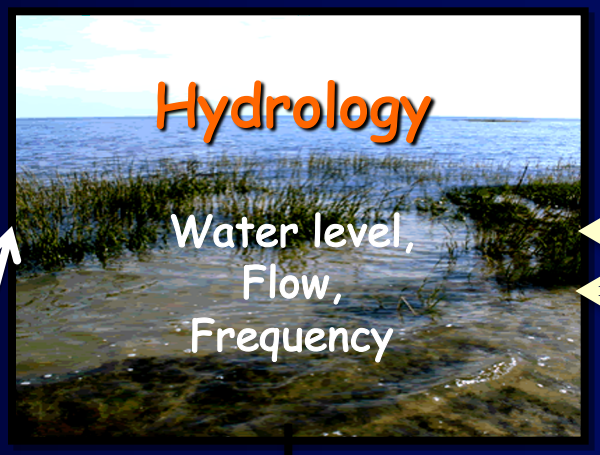
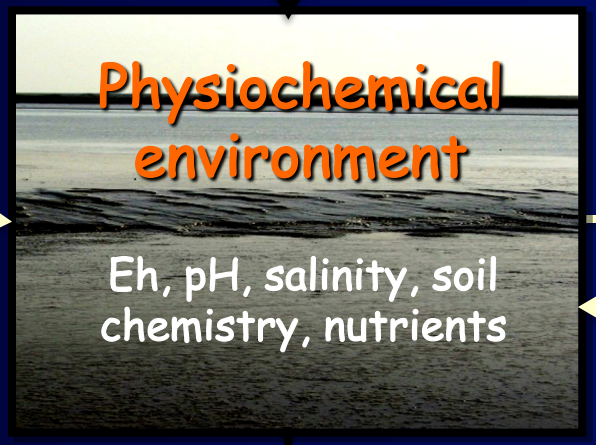
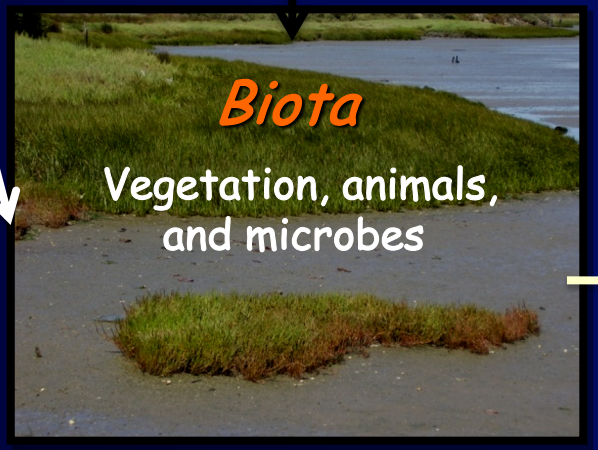
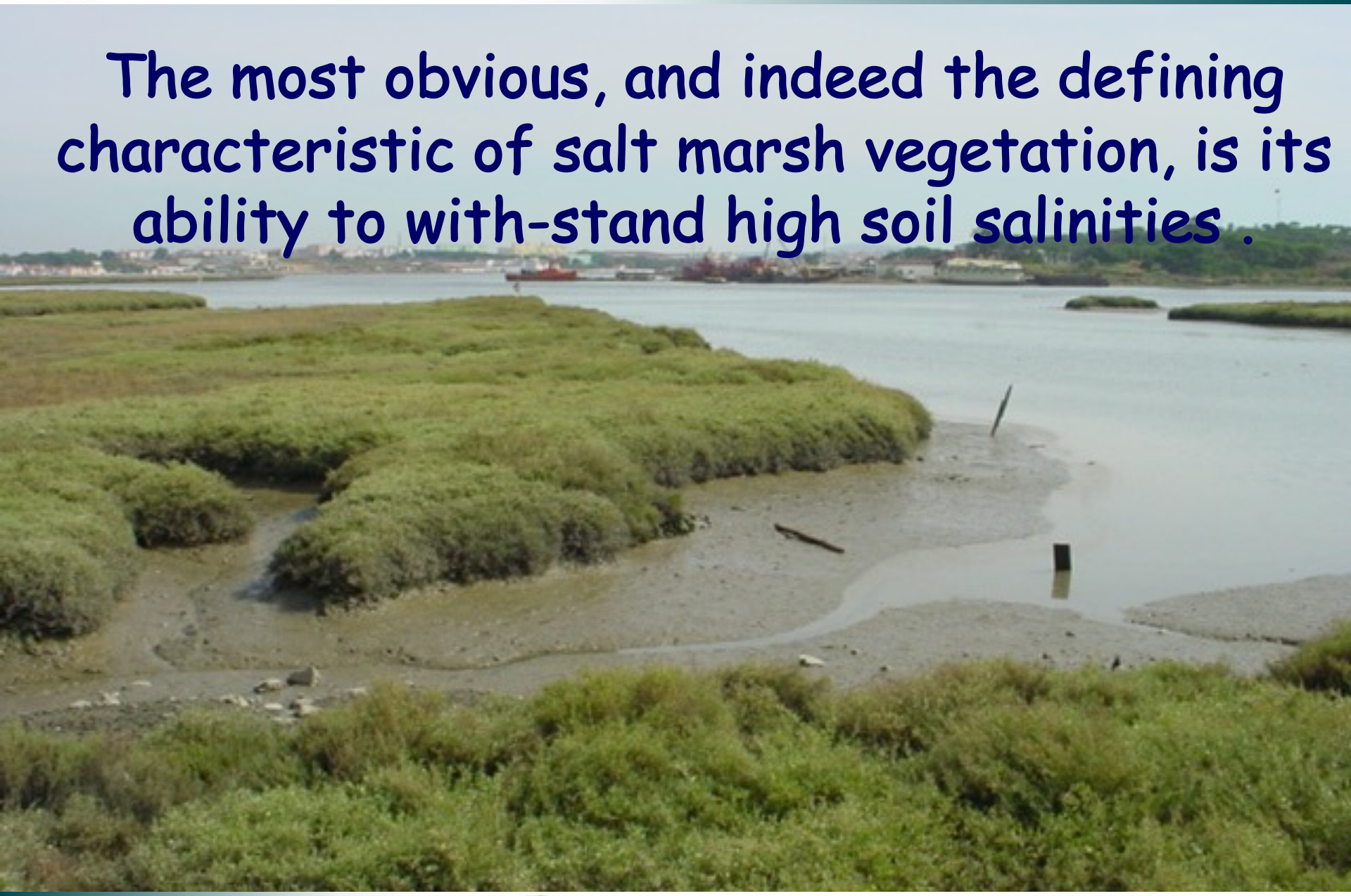
Determinants Factors







To survive in these conditions the plants needs to have some special adaptations to avoid some stress factors such as salinity, flooding and recently heavy metals



The most obvious, and indeed the defining characteristic of salt marsh vegetation, is its ability to with-stand high soil salinities .

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A second effect of tidal inundation for significant areas of salt marsh is waterlogging.

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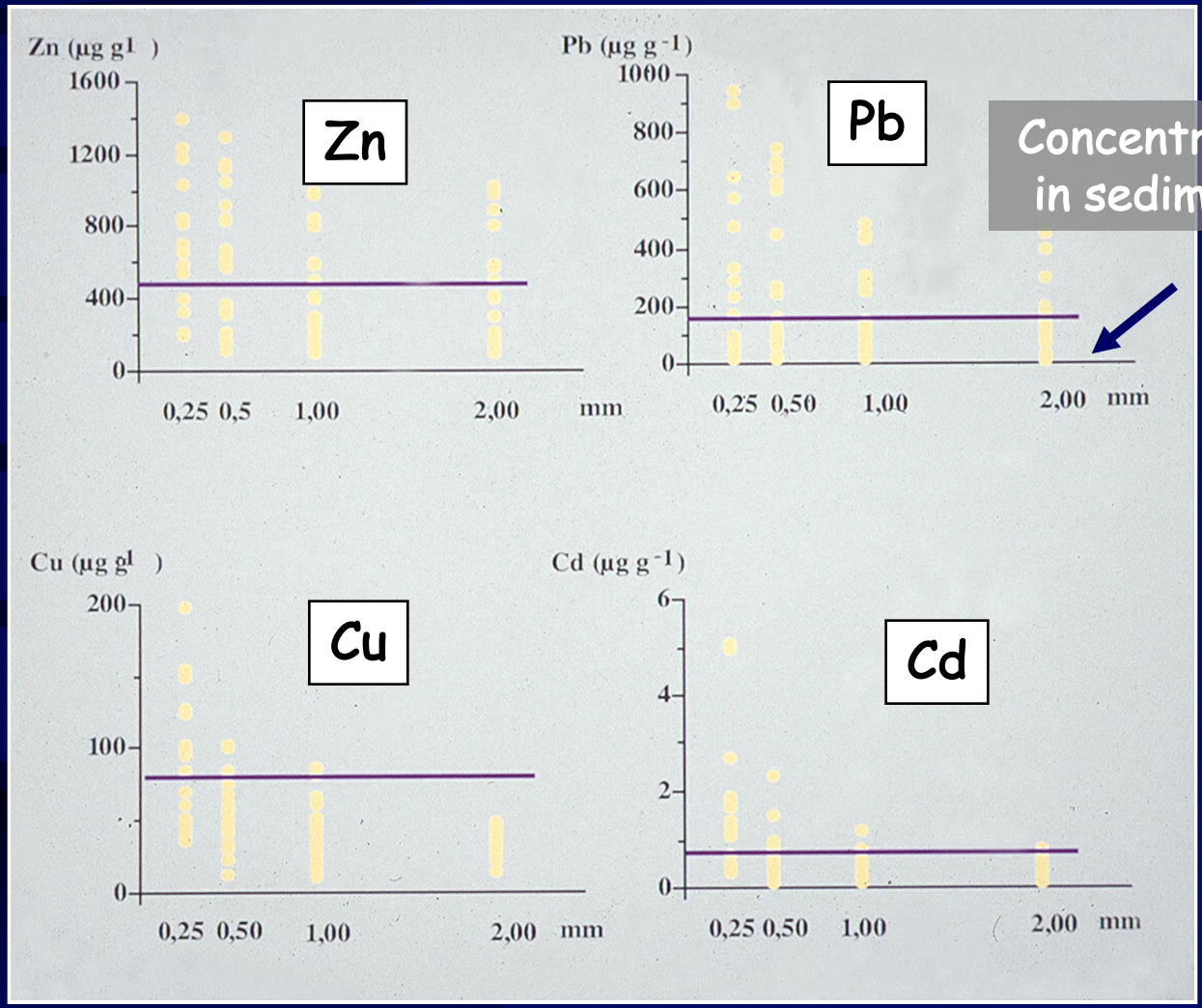
Releasing oxygen to the rhizosphere, vascular plants critically impact the biogeochemistry of the sediments, modifying dramatically the soil characteristics in areas colonised by salt marsh vegetation. The presence of rhizoconcretions is an example

Heavy metal concentrations in rhizoconcretions



Concentrations of Zn,Pb, Cu and Cd in rhizoconcretions (o) and in sediments between roots (-)

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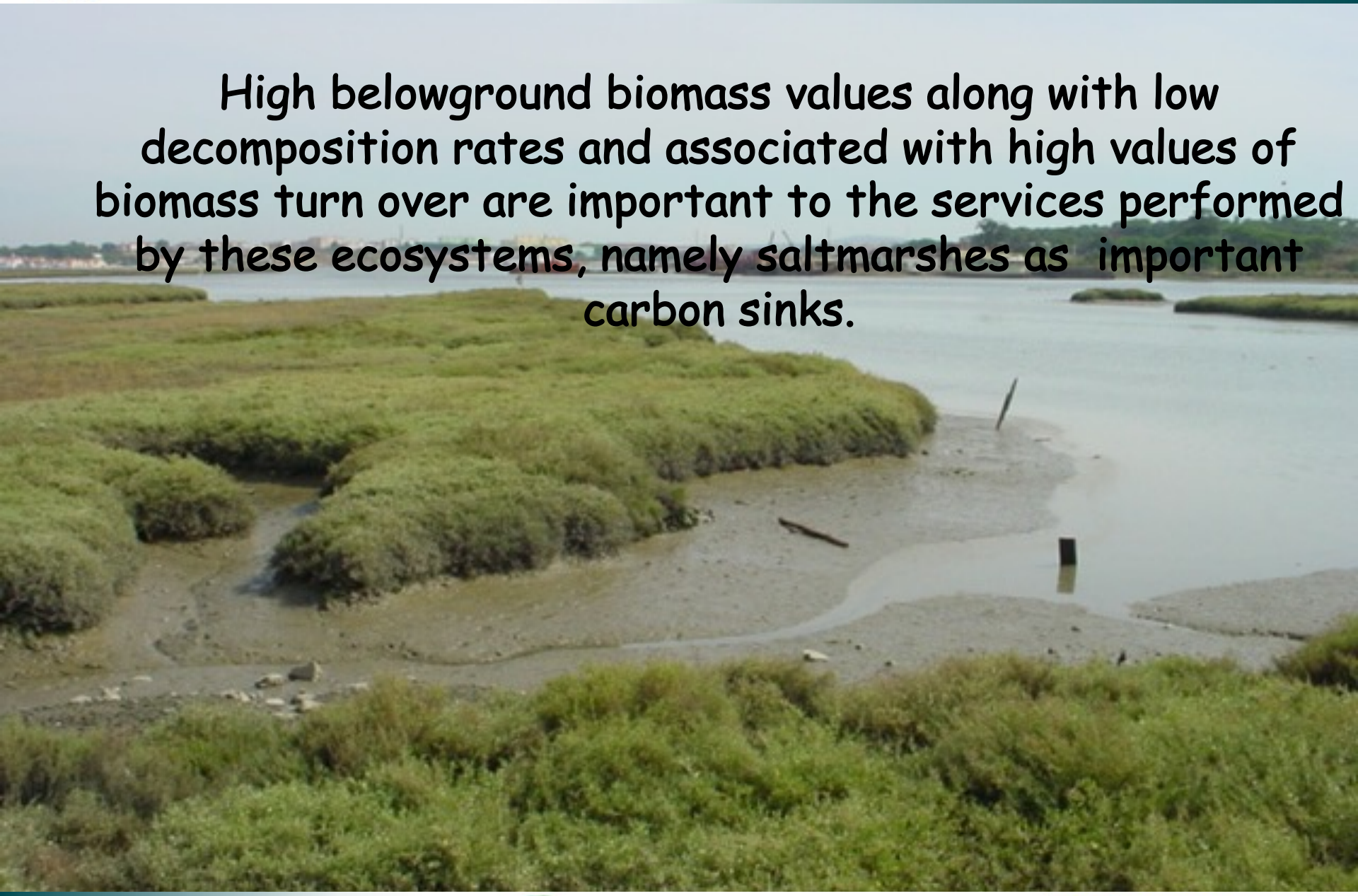
•Here we have the Zn, Pb, Cu and Cd concentrations obtained in rhizoconcretions with different sizes and in sediment between the roots. As you can see rhizoconcretions may accumulate heavy metals, often in concentrations higher than those found in nearby sediments.



High belowground biomass values along with low decomposition rates and associated with high values of biomass turn over are important to the services performed by these ecosystems, namely saltmarshes as important carbon sinks.

Salt marshes and metal retention

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Salt marshes are complex coastal environments usually located within estuarine systems.

Estuaries receive important inputs of pollutants as they are often situated in the vicinities of highly populated and industrialised areas.

Metals transported by the tidal currents, both in dissolved and particulate forms, are eventually incorporated into the surface sediment of salt marshes.

Vegetation may act as sediment traps playing an important role in the settling of suspended estuarine material and their associated metal.

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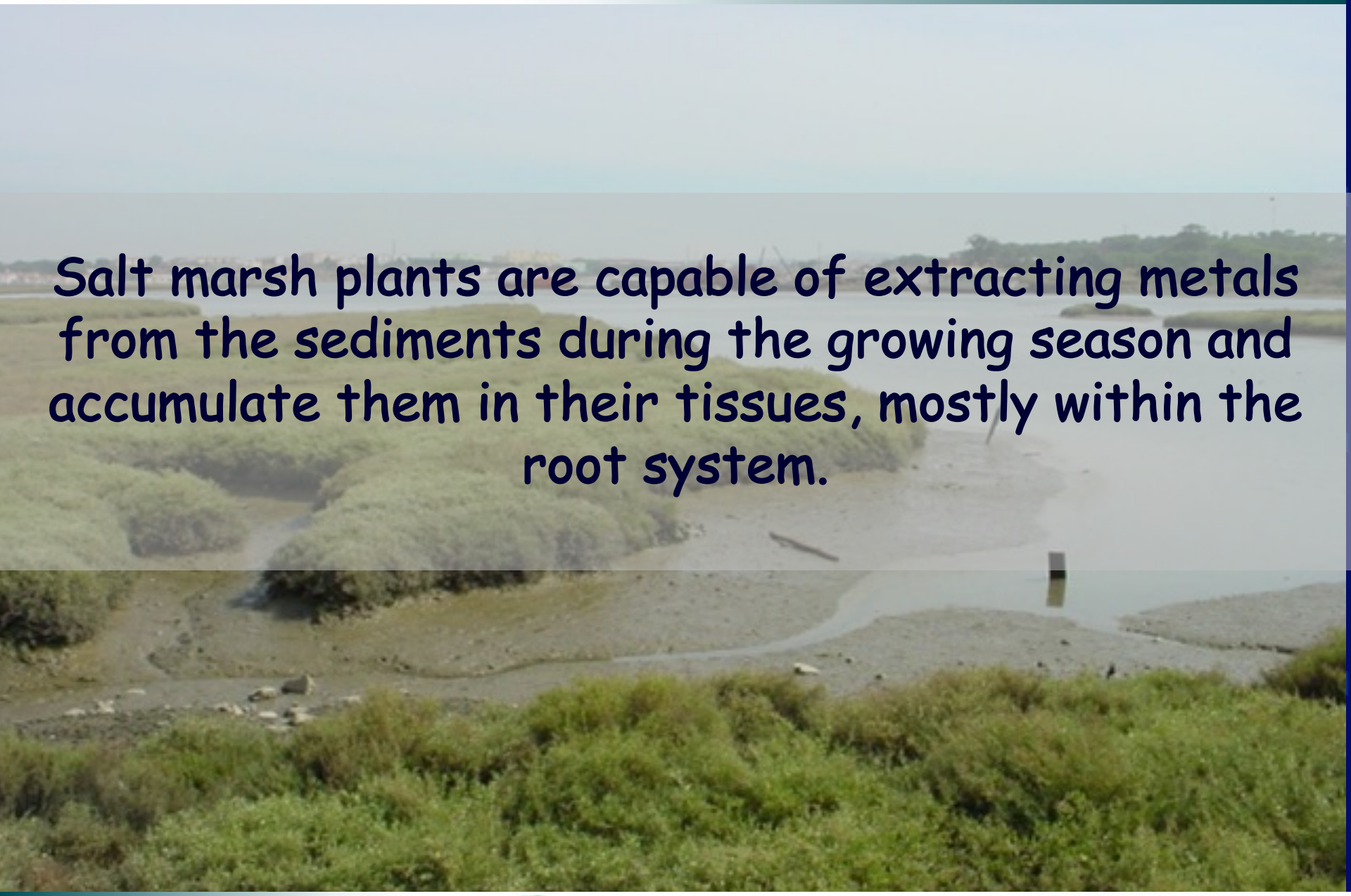
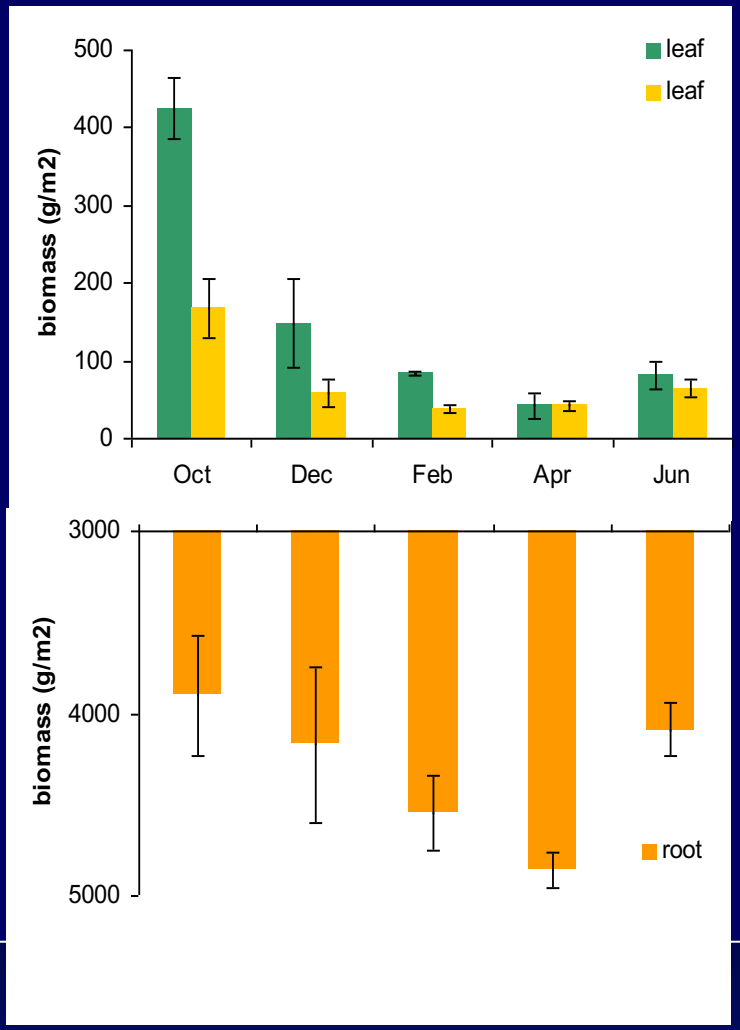
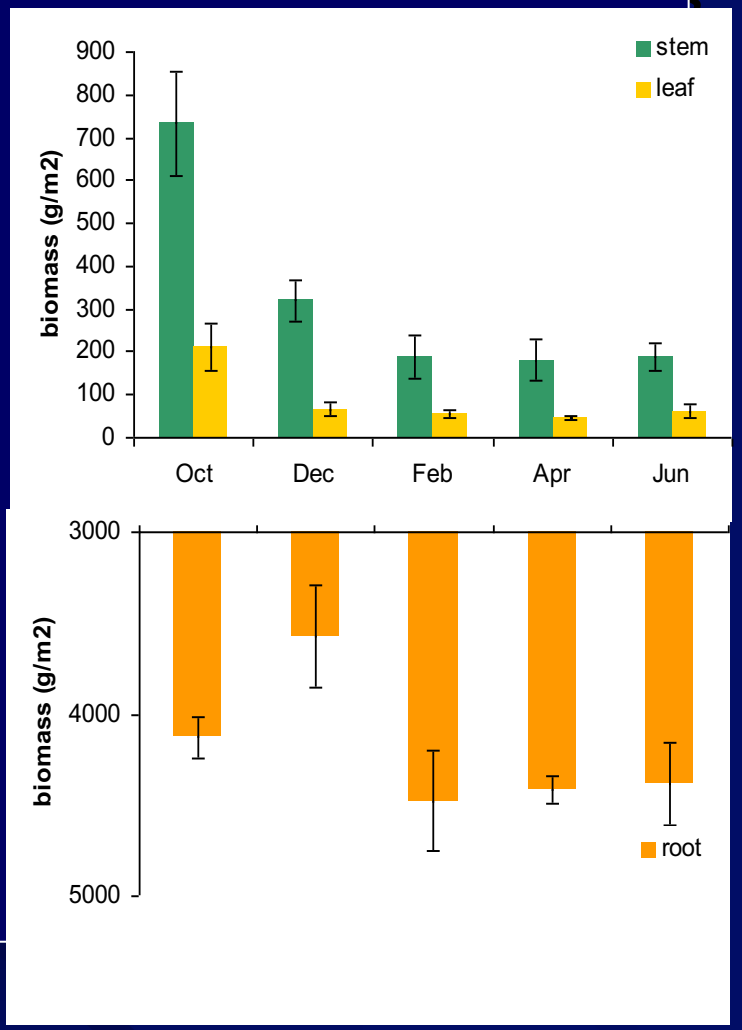


Salt marsh plants are capable of extracting metals from the sediments during the growing season and accumulate them in their tissues, mostly within the root system.

Biomass partition

Aboveground





Belowground

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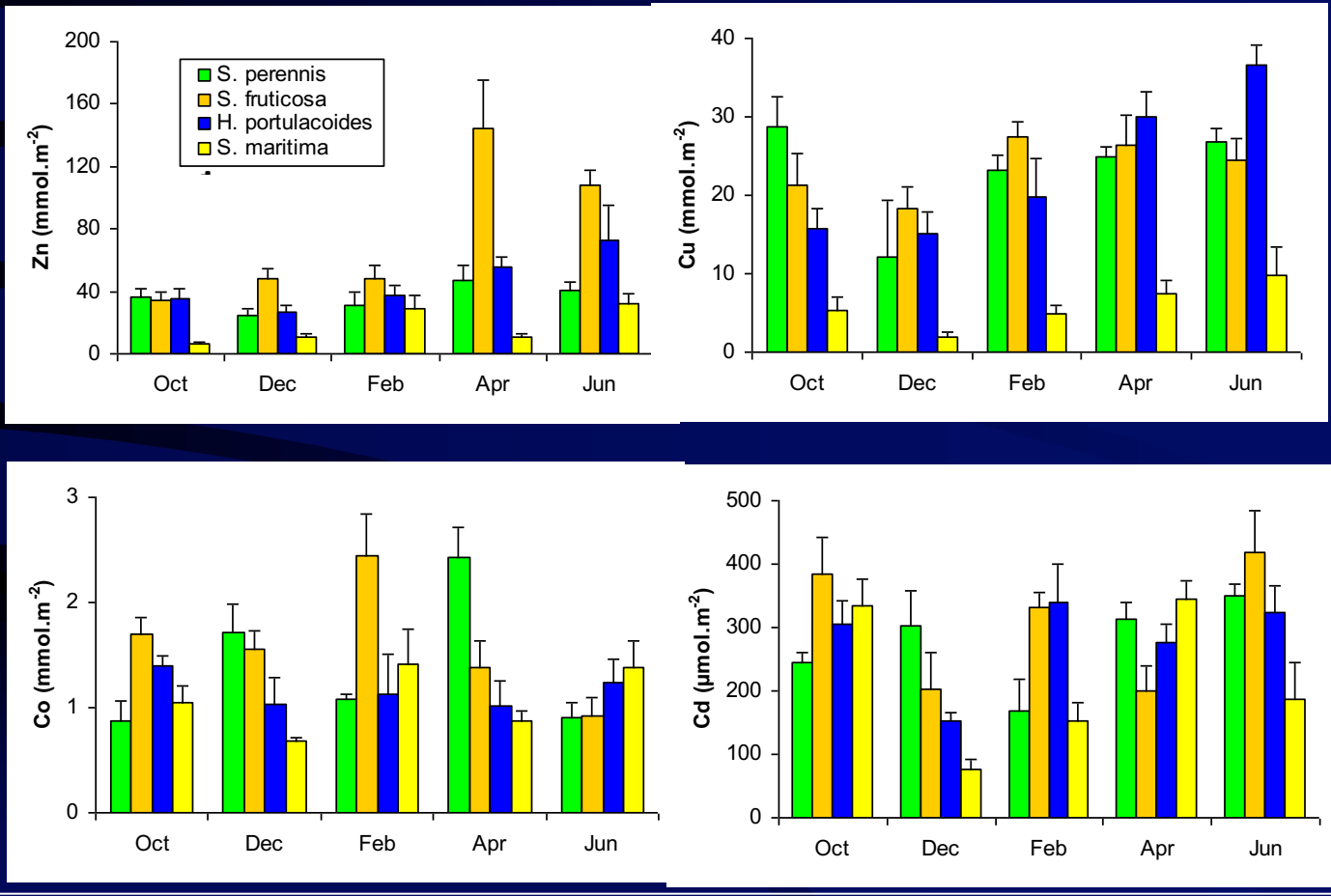
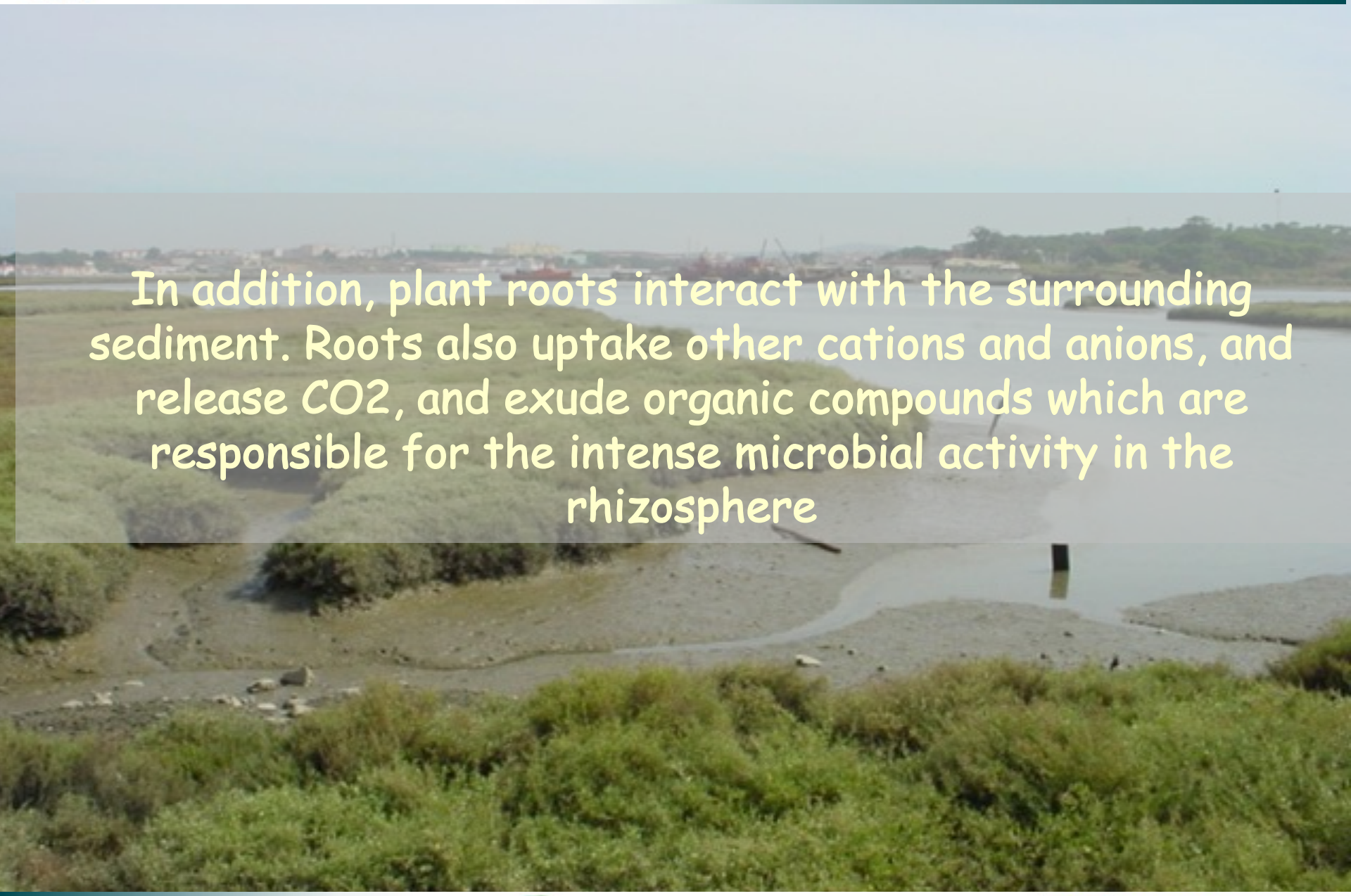
Salt marsh plants are an important temporary sink of metals



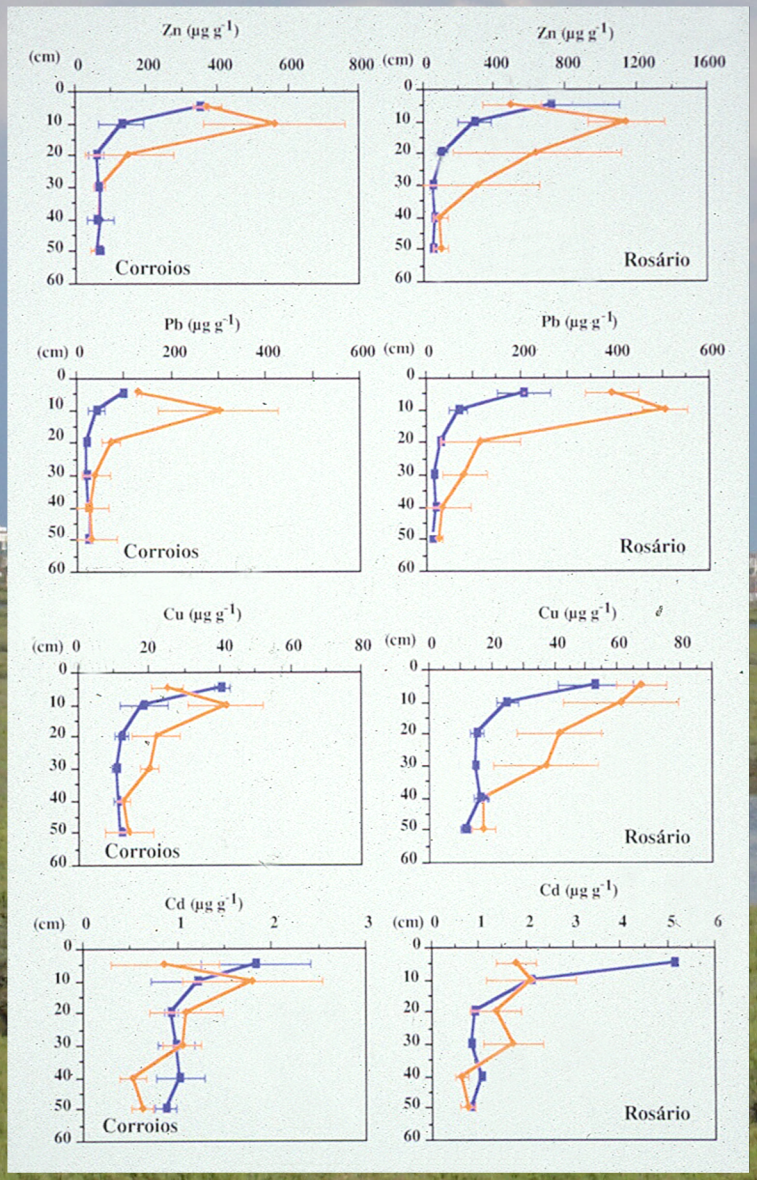
Metal stocks in plants (plant biomass x metal concentration)

Belowground biomass values are very high when compared with aboveground biomass values. The values varied between 3 and a half kg in *Halimione portulacoides* and about 5 kg/m2 in *Spartina maritima*. The highest values registered in the above ground biomass belongs to Halimione portulacoides 700 g. The belowground biomass is about 90 % of the total biomass

•Salt marsh plants take up metals from the sediments and accumulate them in their tissues. Standing stocks at the whole plant scale (metal pools) were consistently lower in *S. maritima*, as a result of comparatively low biomass.



In addition, plant roots interact with the surrounding sediment. Roots also uptake other cations and anions, and release CO2, and exude organic compounds which are responsible for the intense microbial activity in the rhizosphere



Vertical profiles (mean SD, n=3) of total Zn, Pb, Cu and Cd concentrations (µg µg-1 dry weight) in vegetated and non vegetated sediments

plant

sediment

- When we compare vertical profiles of metal concentratios in sediment colonized by plants and in non-vegetated sediments we see that vertical profiles of Zn concentrations in vegetated areas differ in shape and concentrations of those found in non vegetated sediments. The major characteristic is the appearance of a subsurface maximum of several metals
- Concentrations peaks are formed at depths of higher rooting density, and levels in the upper 30cm were higher than those in the corresponding layers of nonvegetated sediments. These differences are clearly related to the presence and activity of roots

Roots may affect substantially the chemistry of sediment layers

containing high below-ground biomass.

The interaction between roots and sediments is exceedingly complicated, covering a wide range of chemical, physical, and biological processes.

Vascular plants in salt marshes are determinant to the dynamics of the estuarine system.

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The presence of oxygen at the root-sediment interface creates local oxidizing conditions in otherwise reducing sediments.

This affects in particular the chemistry of iron and manganes, whose soluble reduced forms diffuse toward these interfaces, where they are precipitated as insoluble iron and manganese oxides.

Thin redish brown deposits on plant roots have been observed on several flood-tolerant plants and attributed to the oxidative capacity of roots.

Other metals are also associated with these iron plaques, reaching higher concentrations than those found in the bulk sediments.

The rhizoconcretion may accumulate heavy metals, often in concentrations higher than those found in nearby sediments.

So rhizoconcretion formation thus contributes to salt marshes acting as natural sinks for trace elements from anthropogenic origin.

The halophyte influence on metal availability

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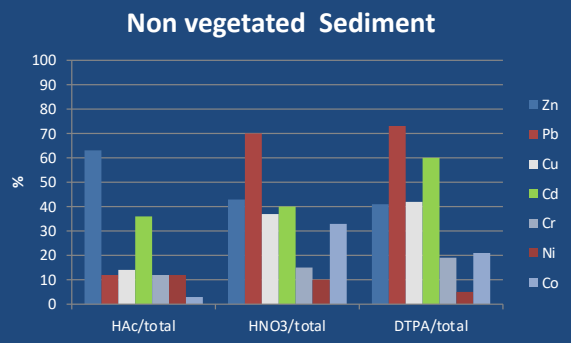
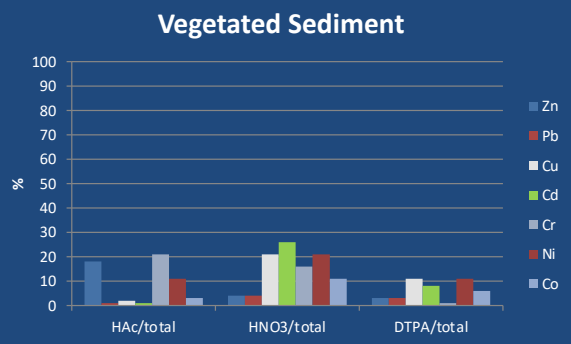
Effect of saltmarsh plants on metal availability (Zn, Pb, Cu, Cd, Cr, Ni e Co)





Corroios Saltmarsh

In this slide we compare the amount of metals removed by weaker extractions from the sediment between roots and non vegetated sediments. Metal recoveries at both sites were expressed as percentages of total metal concentrations. For each element, values varied with the extraction procedure and the sediment type. The percentage of Zn, Pb, and Cu removed by the thre extractions from vegetated sediments were much lower than those recovered from non-vegetated sediments. For Ni and cr such differences were not found

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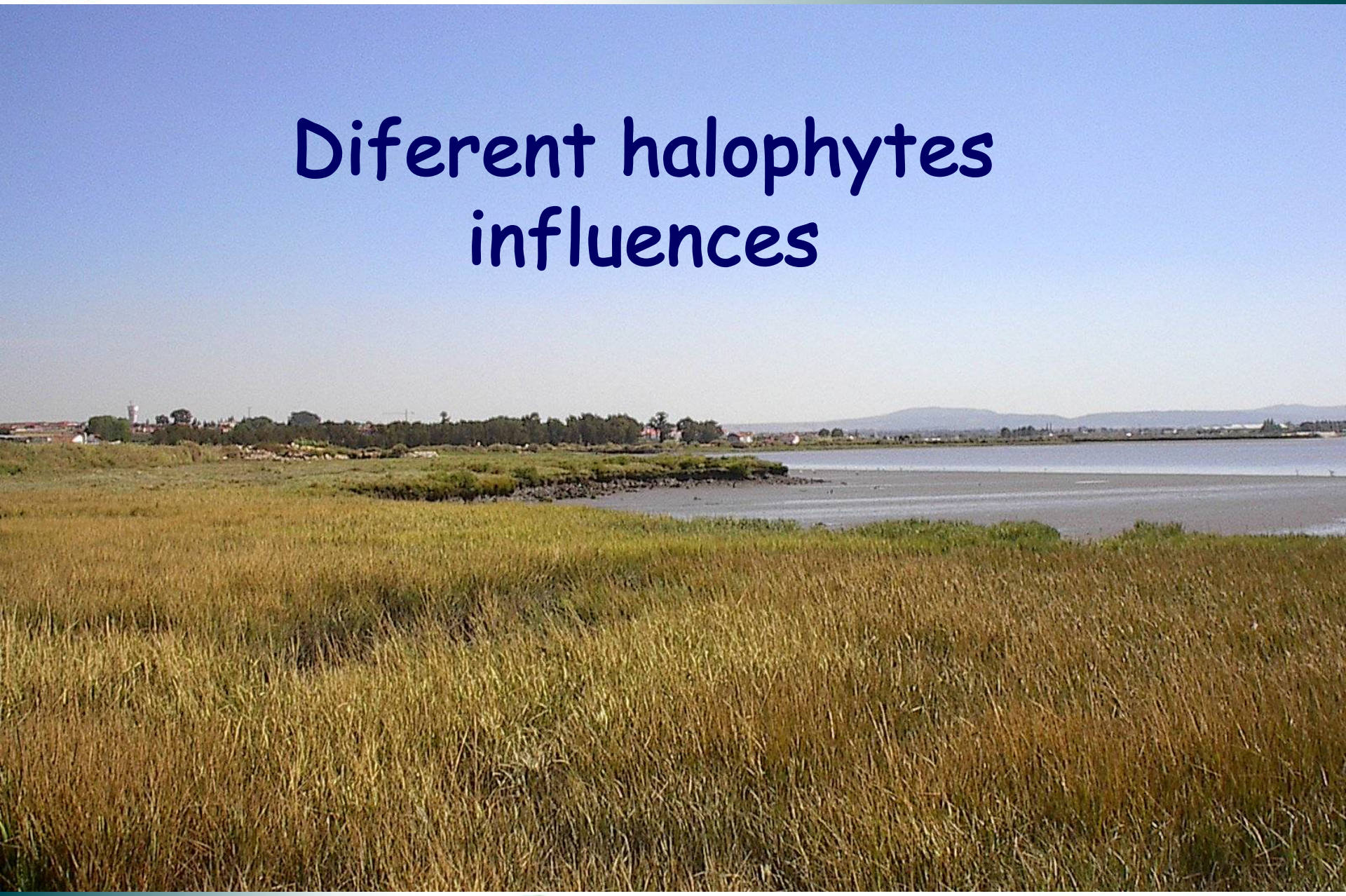
Diferent halophytes influences



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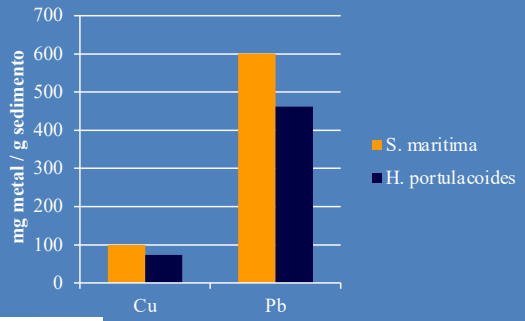
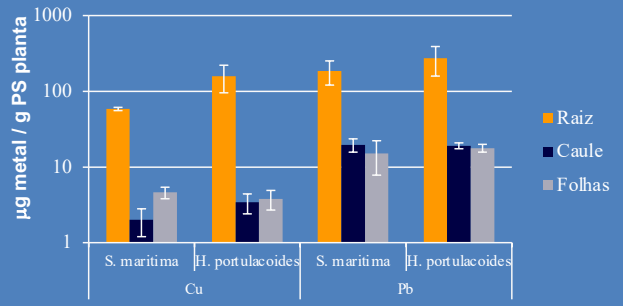
Halophyte influence in metal speciation

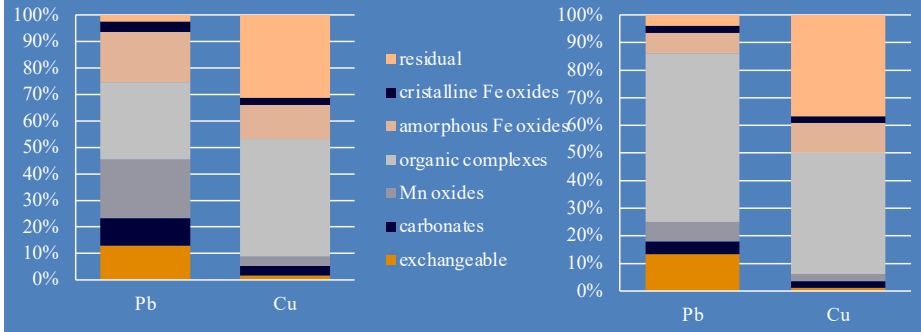
Sediment



Plant



Metal speciation



Halimione portulacoides

Spartina maritima

Also the plant species is important influencing the sediment biochemistry. Root activity, plant physiology are also important factores influencing metal availability. Different halopytes, different influences. Sediment colonised by *Spartina maritima* has higher concentrations of Cu and Pb than sediments colonised by *Halimione potulacoides*. Metal speaciation is also different in sediments colonized by Spartina maritima and sediments colonized by *H. portulacoides*. The sediment colonized by *Spartina* is richer in residual forms when compared with sediment colonized by *Halimione*. Furthermore *Halimione* show the highest metal concentrations in the tissues

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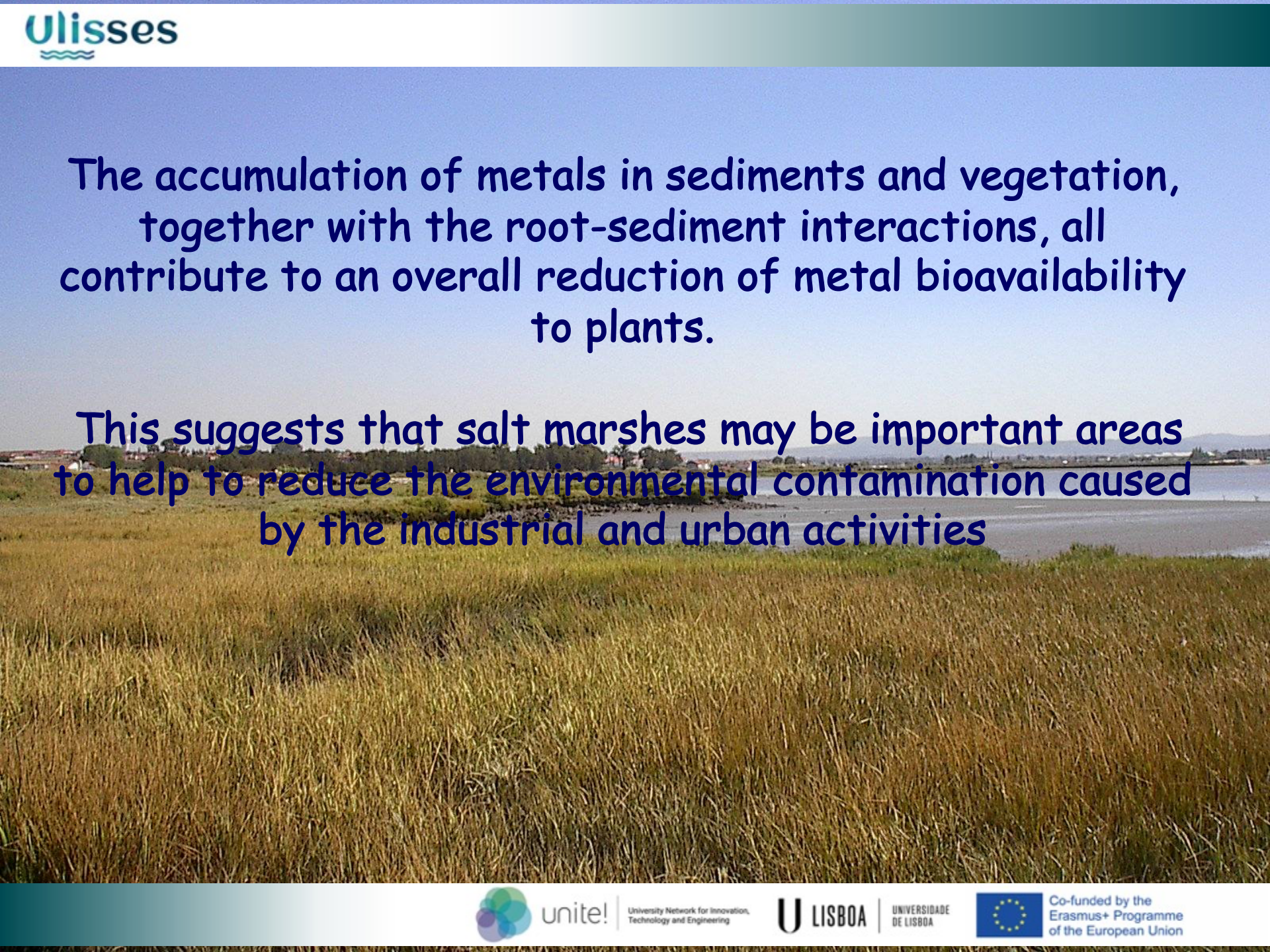

The accumulation of metals in sediments and vegetation, together with the root-sediment interactions, all contribute to an overall reduction of metal bioavailability to plants.

This suggests that salt marshes may be important areas to help to reduce the environmental contamination caused by the industrial and urban activities

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