Zostera noltei as a NbS for the restoration of degraded estuarine ecosystems – An overview of project RemediGrass

Vítor H. Oliveira; A.I. Sousa; D. Crespo; C.L. Mieiro; B.A. Fonte; B. Marques; V. Freitas; J.M. Dias; N. Vaz; D. Matos; A. Carvalhais; F. Costa; R. Faião; E. Figueira; C.B. Lopes; B. Henriques; M. Pacheco; M.E. Pereira; R. Calado; A. I. Lillebø; S. Díez; M. Dolbeth; J.P. Coelho

Universidade de Aveiro

CESAM CENTRE FOR ENVIRONMENTAL AND MARINE STUDIES

ciimar

idaea

CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS

FCT Fundação para a Ciência e a Tecnologia

REPÚBLICA PORTUGUESA

Study area

Study area: **Ria de Aveiro** (or Aveiro Lagoon)

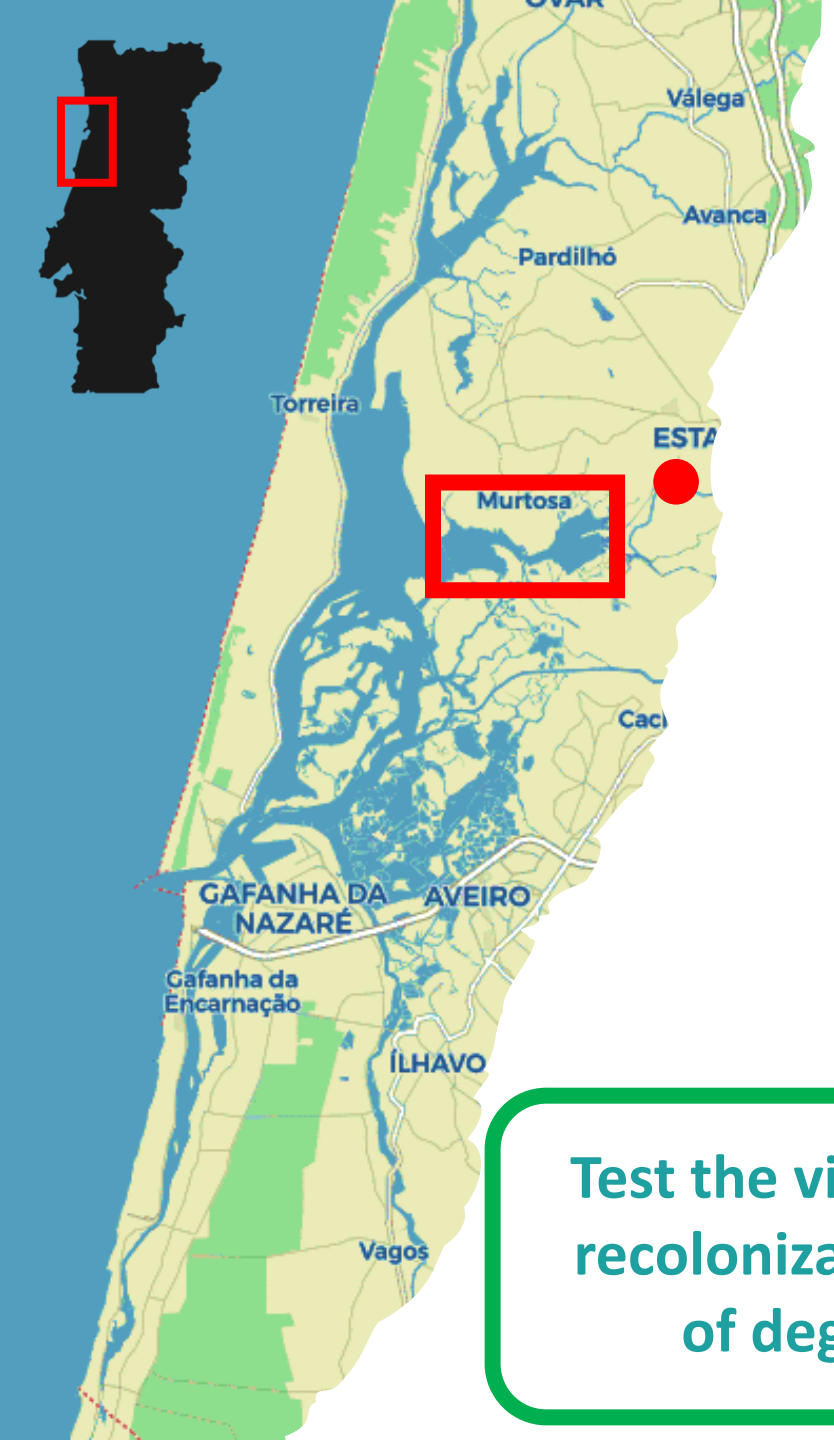
Contamination source

Is it possible to restore this area?

Contamination source: Estarreja Chemical Complex

- ✓ Arsenic [As]
- ✓ Cadmium [Cd]
- ✓ Copper [Cu]
- ✓ Mercury [Hg]
- ✓ Nickel [Ni]
- ✓ Lead [Pb]
- ✓ Zinc [Zn]
- ✓ (…)

Motivation



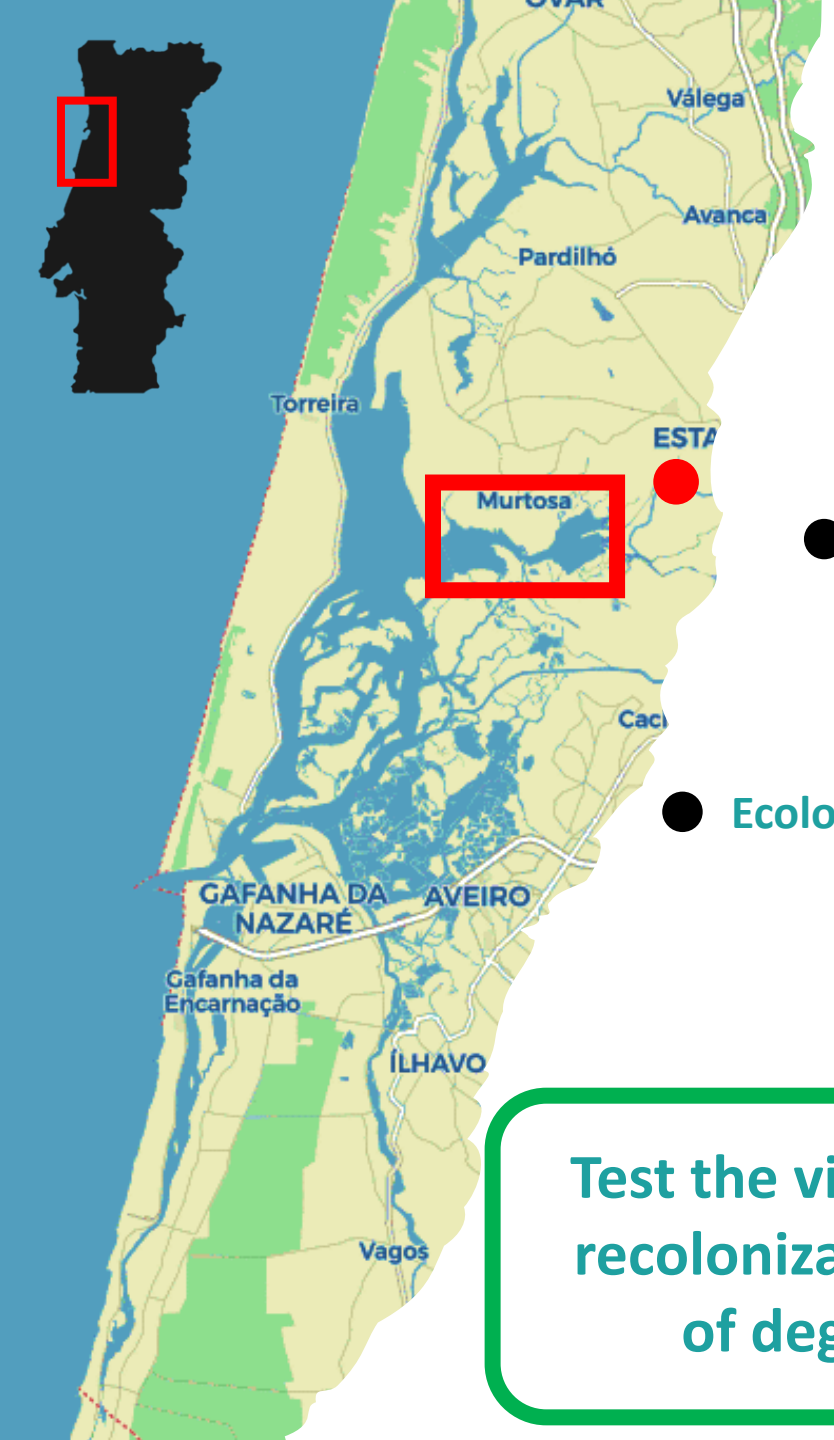
- Loss of fauna and flora

© Fernando Correia. TODOS OS DIREITOS RESERVADOS

Test the viability and efficiency of seagrass recolonization as a NbS for the restoration of degraded estuarine ecosystems

Zostera noltei (Z. noltei)

Motivation



- Loss of fauna and flora

- Sociocultural value → Fertilize agricultural soils

- Ecological functions
  - ✓ Habitat
  - ✓ Stabilize sediment
  - ✓ (…)

Test the viability and efficiency of seagrass recolonization as a NbS for the restoration of degraded estuarine ecosystems

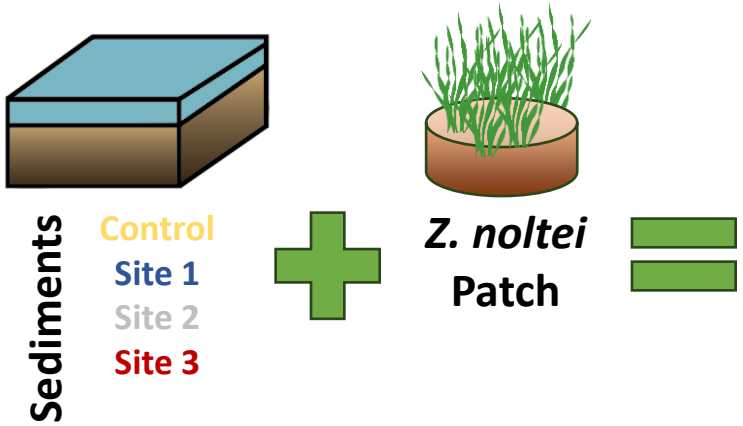
→ *Zostera noltei (Z. noltei)*

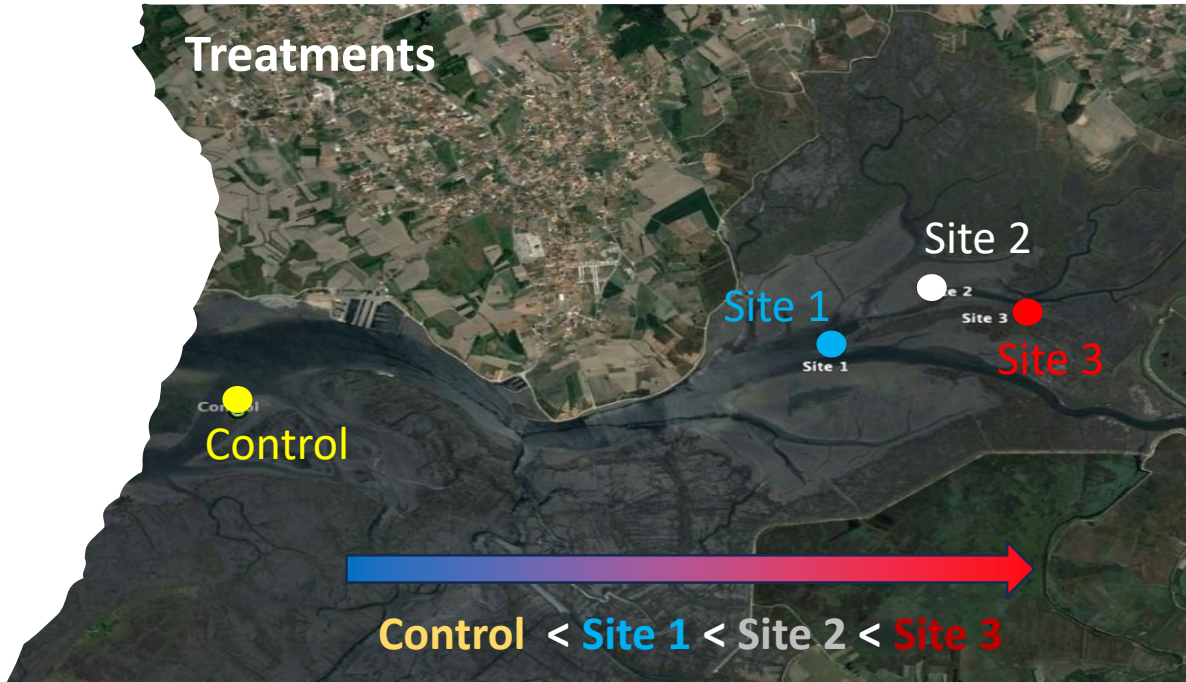
Mesocosm experiment

- ✓ **Test tolerance and resistance** of *Z. noltei* when exposed to contaminants

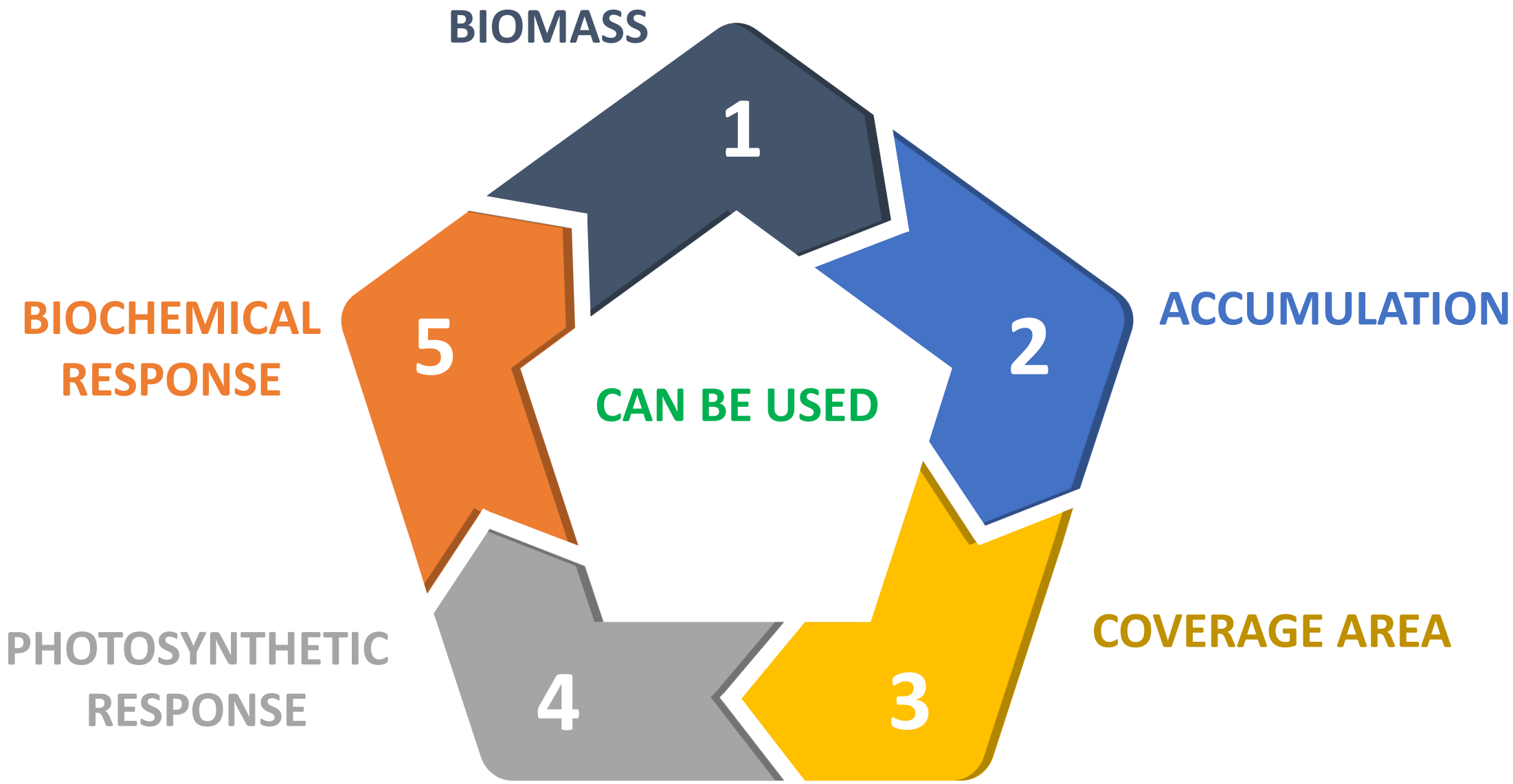
Mesocosm experiment

- **Biomass**
- **Accumulation**
- **Coverage area**
- **Photosynthetic** response
- **Biochemical** response





Mesocosm experiment (Conclusion)



Fonte, B.A. *et al.* (2023). Zostera noltei response to transplantation into historically Hg-contaminated sediments (A mesocosm experiment): Growth, bioaccumulation and photosynthetic performance. https://doi.org/10.1016/j.chemosphere.2023.139374
Oliveira, V.H. *et al. (*2025). Seagrass biochemical response to transplantation into contaminated sediments: A mesocosm experiment. https://doi.org/10.1016/j.envres.2025.121353

Transplant experiment

- ✓ **Monitoring** the field transplant experiment

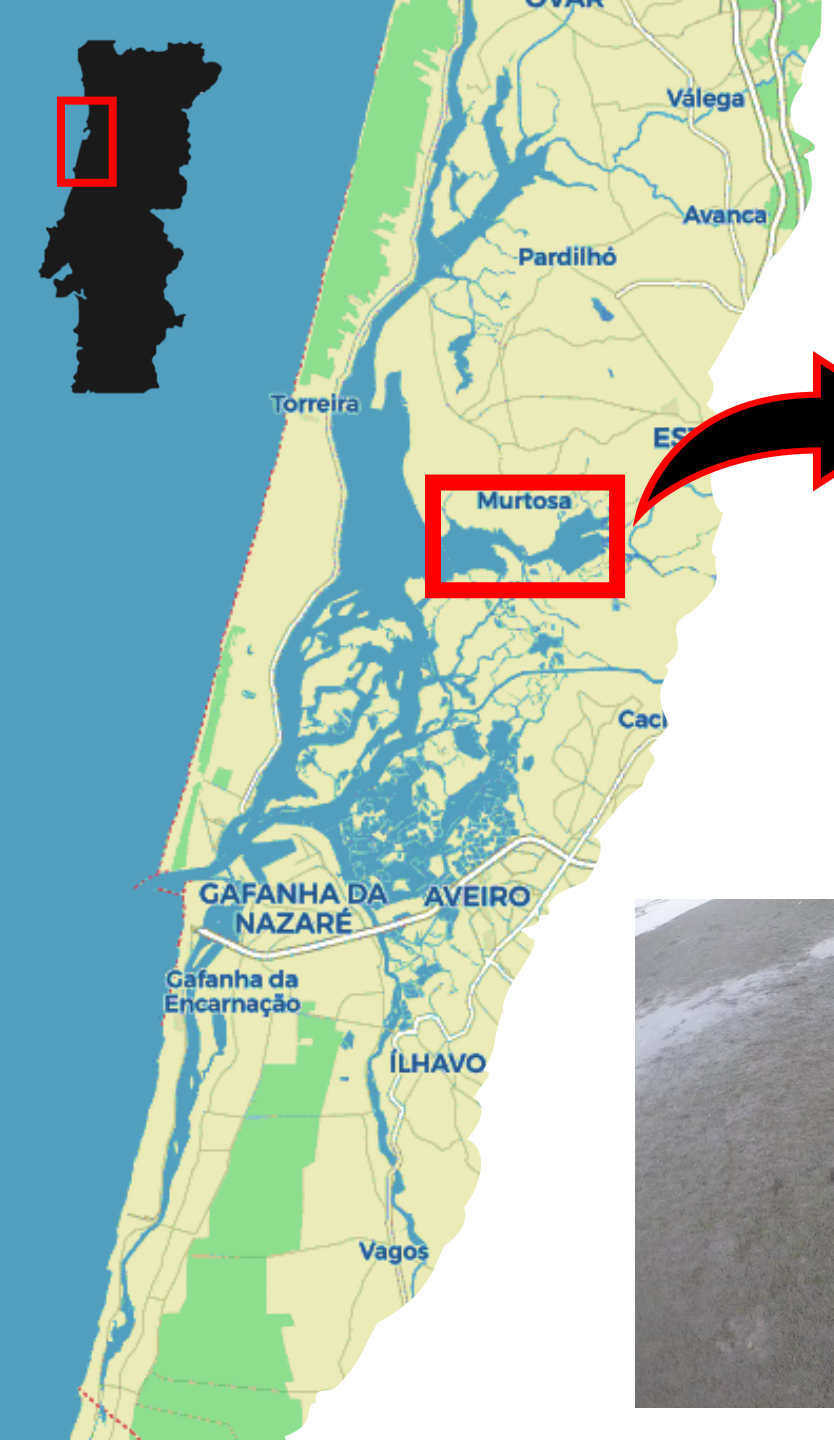
Site selection

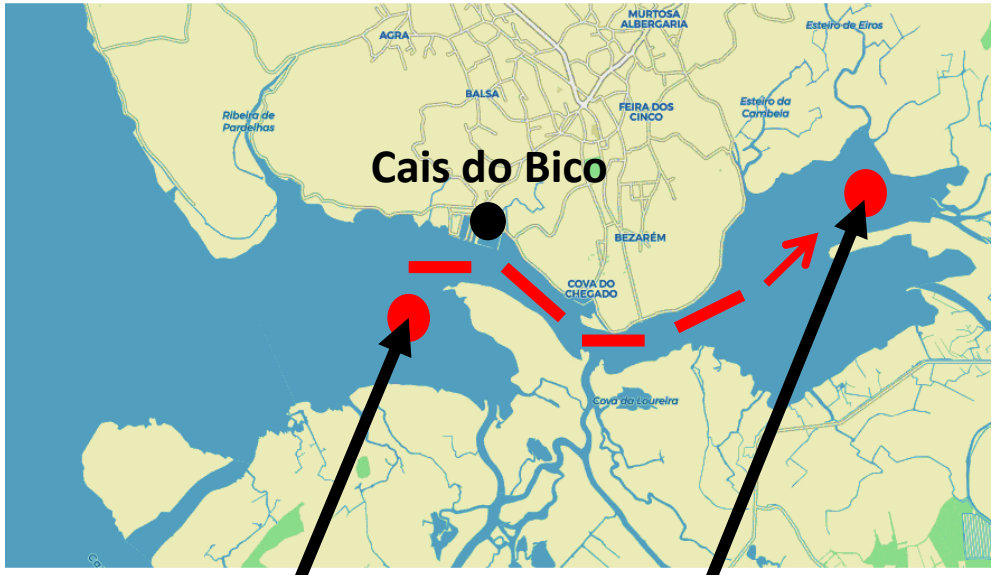
Numerical model: Delft3D

- ✓ Maximum depth
- ✓ Emersion and submersion periods
- ✓ Currents

What is the best site?

Transplant



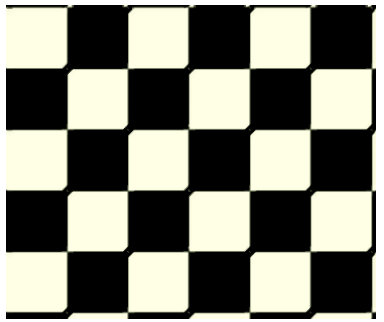


Donor meadow

Transplant meadow

Válega
Avanca
Pardilhó
Torreira
Murtosa
GAFANHA DA NAZARÉ
AVEIRO
Gafanha da Encarnação
ÍLHAVO
Vagos


AGRA
MURTOSA ALBERGARIA
Esteiro de Eiros
BALSA
FEIRA DOS CINCO
Esteiro da Cambeia
Ribeira de Parceinhas
BEZARÉM
COVA DO CHEGADO
Cova da Loureira
Laranjo Bay

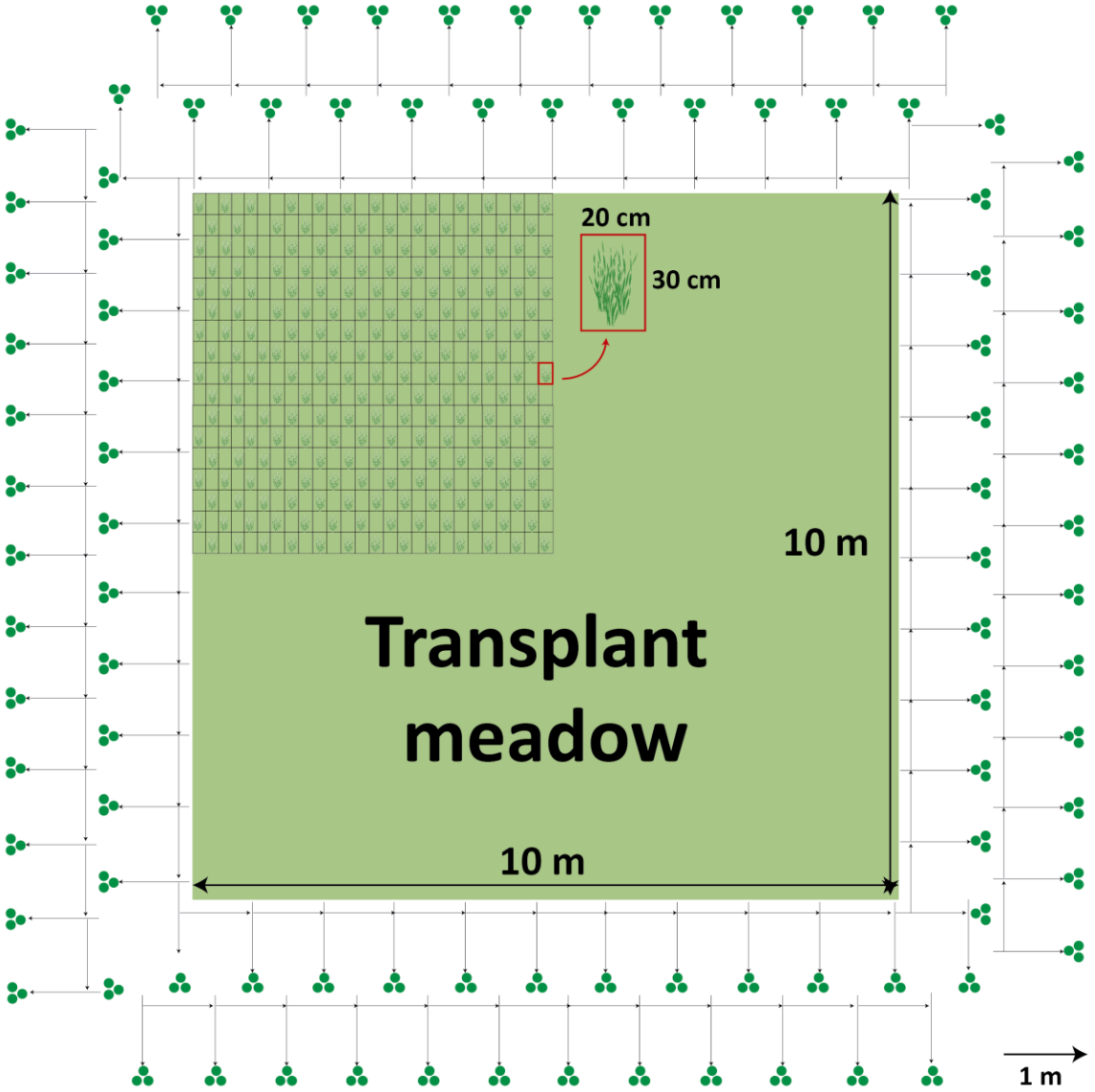


Transplant procedure

Transplant in Laranjo Bay

- 1st transplant – 2020 (summer) ≈ **25 m²**
- Currently (after 5 years) ≈ **300 m²**

Z. noltei* patch (*Mosaic shape)



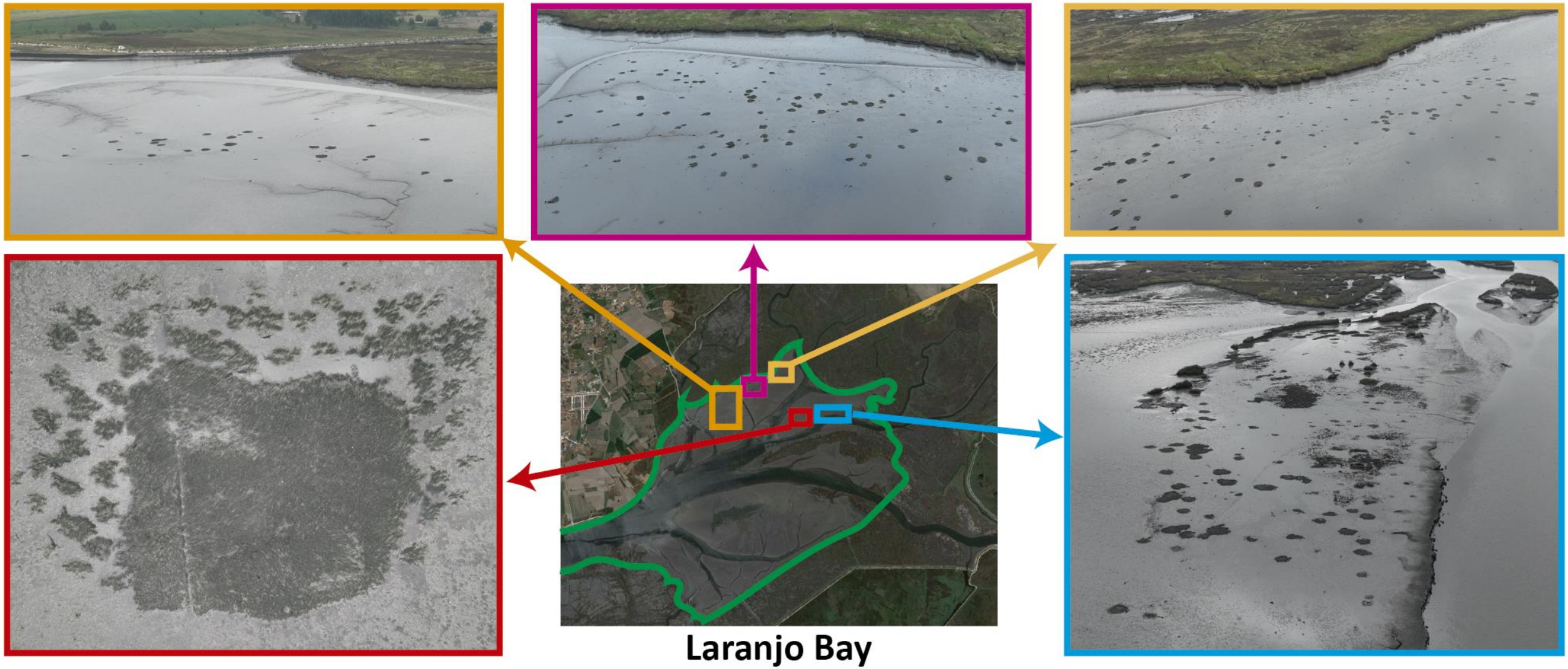
Oliveira, V.H. *et al.* (2025). Transplantation of seagrass (Zostera noltei) as a potential nature-based solution for the restoration of historically contaminated mudflats. https://doi.org/10.1016/j.scitotenv.2024.178257

Monitoring Transplant Evolution

- **Biomass** → Seasonal variations
- **Accumulation** → ≈ mesocosm experiment
- **Coverage area** → ≈ mesocosm experiment
- **Photosynthetic** response → Seasonal variations
- **Biochemical** response → Seasonal variations

Oliveira, V.H. *et al. (*2025). Transplantation of seagrass (Zostera noltei) as a potential nature-based solution for the restoration of historically contaminated mudflats.
https://doi.org/10.1016/j.scitotenv.2024.178257
Oliveira, V.H. *et al. (*2025). Metabolic Response of Zostera Noltei Transplants in a Historically Contaminated Ecosystem.
https://doi.org/10.1016/j.jenvman.2025.124918

Evolution of transplant



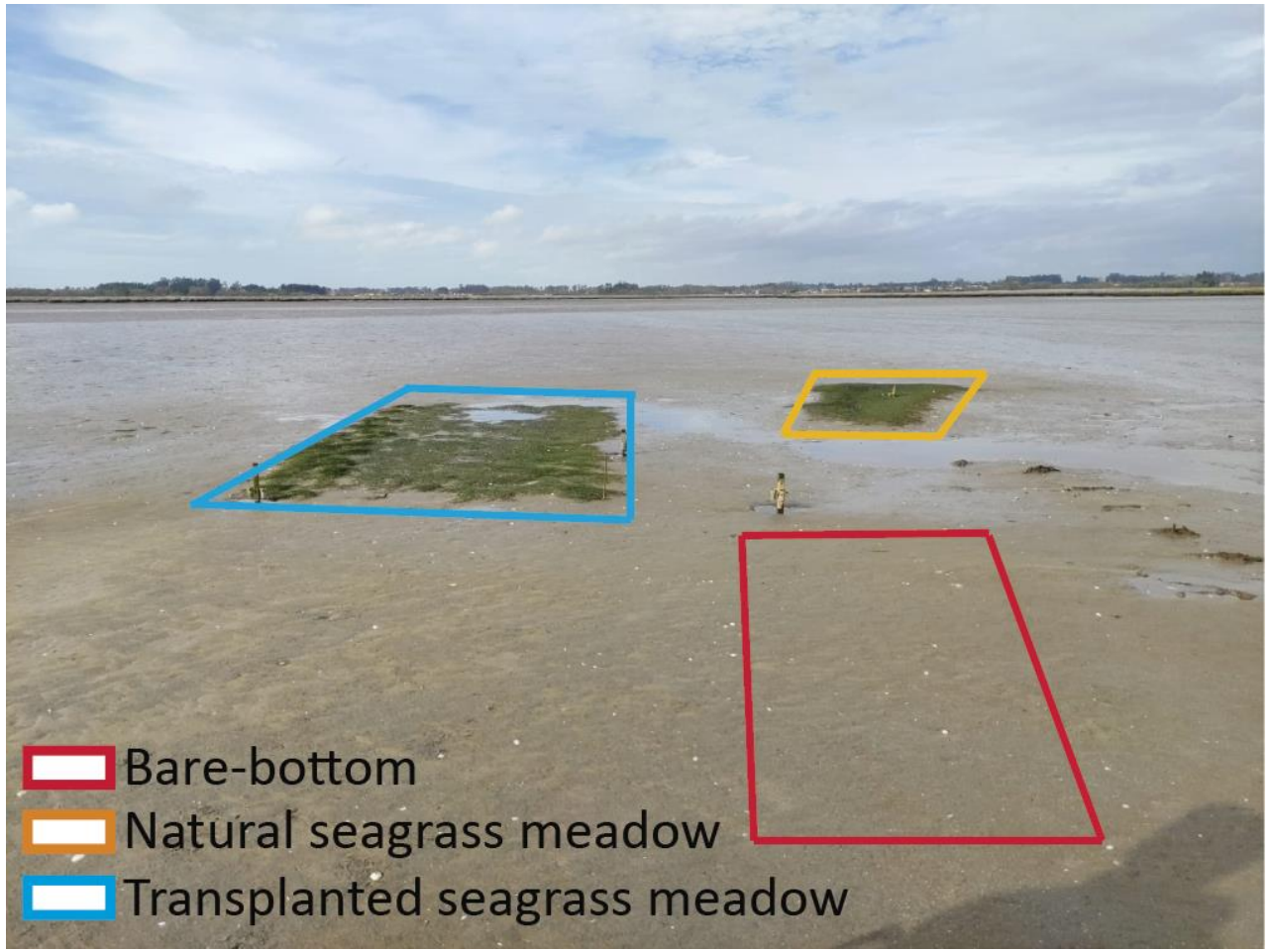
Assess the effect of the *Z. noltei* **presence**

- Contaminant geochemistry
- Bioaccumulation and toxicity in fauna

Effects on geochemistry

Sediments

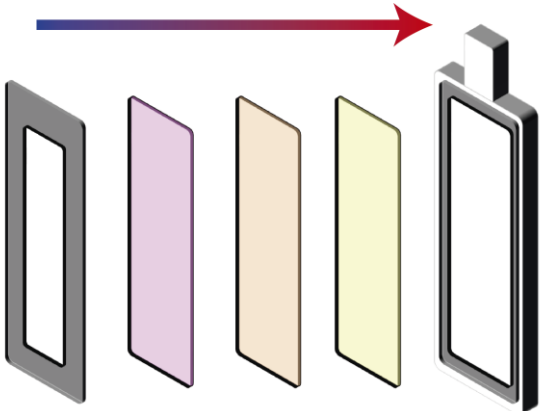
Bioavailable Hg fraction



Sediment corer

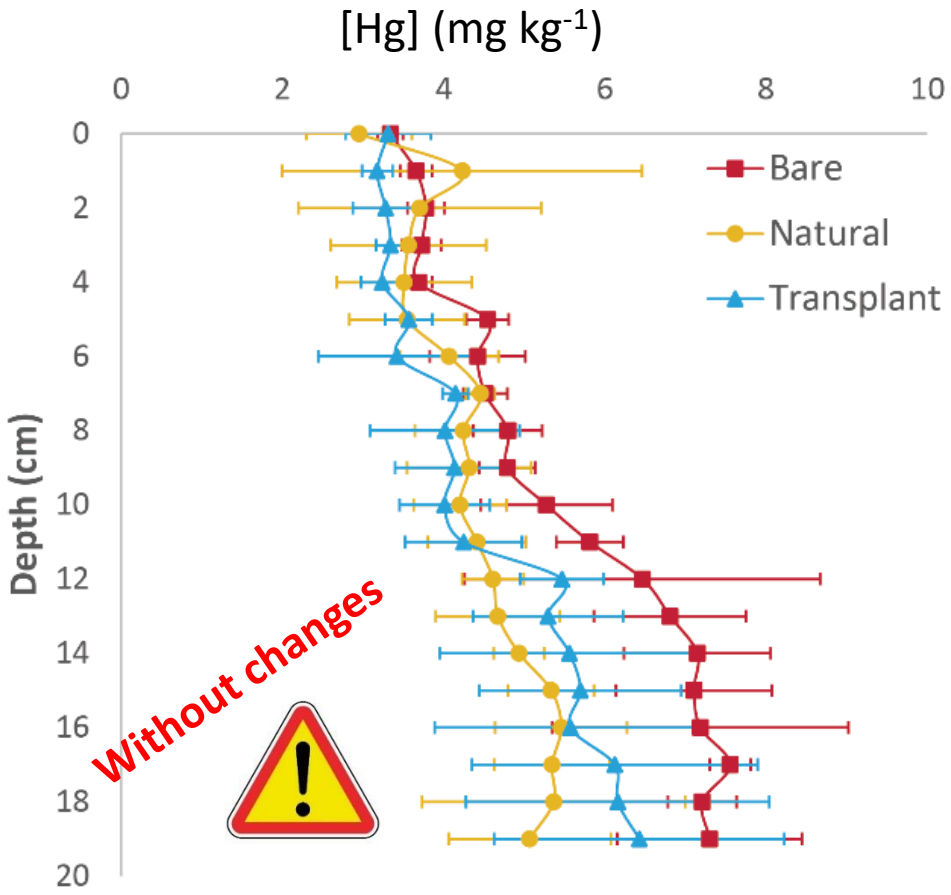
Passive samplers

DGT (diffusive gradients in thin films)

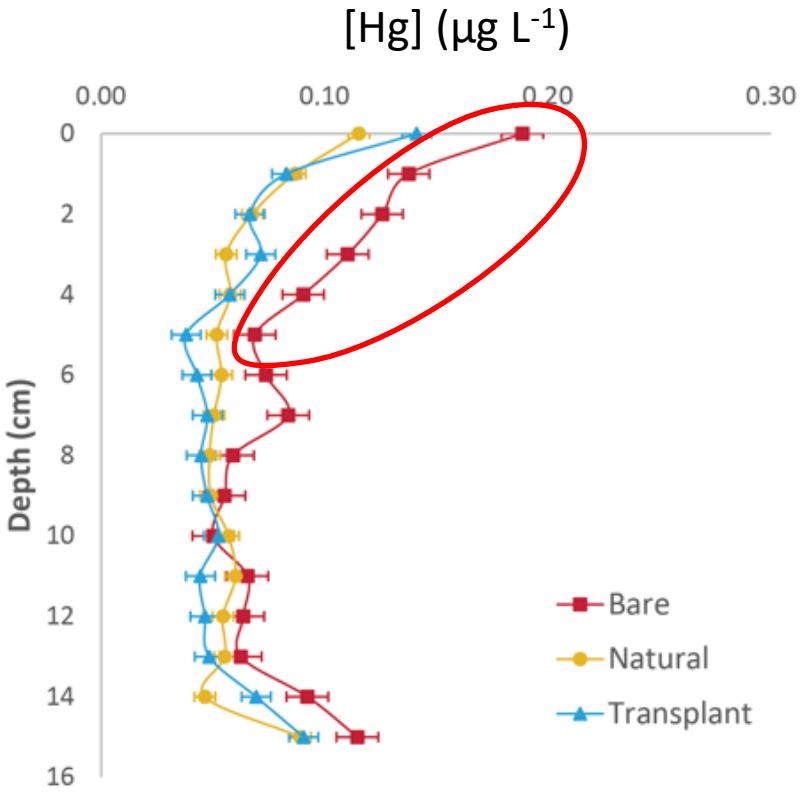


Effects on geochemistry

Hg sediment profiles



Bioavailable Hg fraction



Oliveira, V.H. *et al.* (2023). The effect of Zostera noltei recolonization on the sediment mercury vertical profiles of a recovering coastal lagoon. https://doi.org/10.1016/j.chemosphere.2023.140438

Effects on fauna

Accumulation of Hg / **Biochemical** response

Scrobicularia plana

Hediste diversicolor

→ **Transplant meadow** →

↓ **[Hg]**

↓ **Oxidative damage (e.g., LPO)**

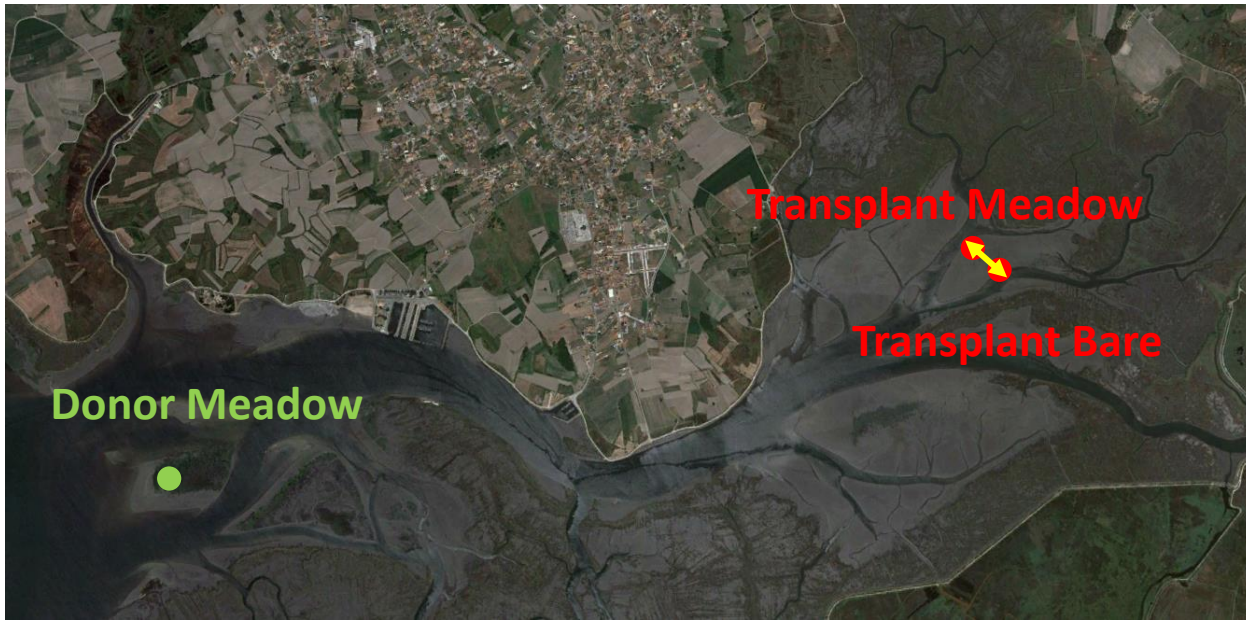
Impact on benthic communities

Transplant meadow →

↑ **Density**

↑ **Total biomass**

≈ **Biodiversity**



Crespo, D. *et al. (*2023). Using seagrass as a nature-based solution: Short-term effects of Zostera noltei transplant in benthic communities of a European Atlantic coastal lagoon. https://doi.org/10.1016/j.marpolbul.2023.115762

Oliveira, V.H. *et al. (*2025). Contaminant bioaccumulation and biochemical responses of the bivalve Scrobicularia plana and the polychaete Hediste diversicolor to ecosystem restoration measures using Zostera noltei. https://doi.org/10.1016/j.envres.2025.121429

Seagrass restoration in contaminated ecosystems promotes ecological recovery

Zostera noltei as a NbS for the restoration of degraded estuarine ecosystems – An overview of project RemediGrass

Vítor H. Oliveira; A.I. Sousa; D. Crespo; C.L. Mieiro; B.A. Fonte; B. Marques; V. Freitas; J.M. Dias; N. Vaz; D. Matos; A. Carvalhais; F. Costa; R. Faião; E. Figueira; C.B. Lopes; B. Henriques; M. Pacheco; M.E. Pereira; R. Calado; A. I. Lillebø; S. Díez; M. Dolbeth; J.P. Coelho

https://remedigrass.web.ua.pt/ vitor.hugo.oliveira@ua.pt

Universidade de Aveiro
CESAM CENTRE FOR ENVIRONMENTAL AND MARINE STUDIES
ciimar
idaea
CSIC CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS
FCT Fundação para a Ciência e a Tecnologia
REPÚBLICA PORTUGUESA