# Spatiotemporal heterogeneity of wetland rhizospheres controls essential wetland ecosystem functions

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# Agenda:

## Introduction

- Spatiotemporal heterogeneity controls important ecosystem functions
- Nitrogen retention in marsh rhizospheres

## Structural heterogeneity in salt marsh rhizospheres

- Biomass structure and gas transport

## Chemical heterogeneity in rhizospheres

- Plant-mediated sediment oxygenation
- Root-mediated $CO_2$ uptake

## Chalk talk

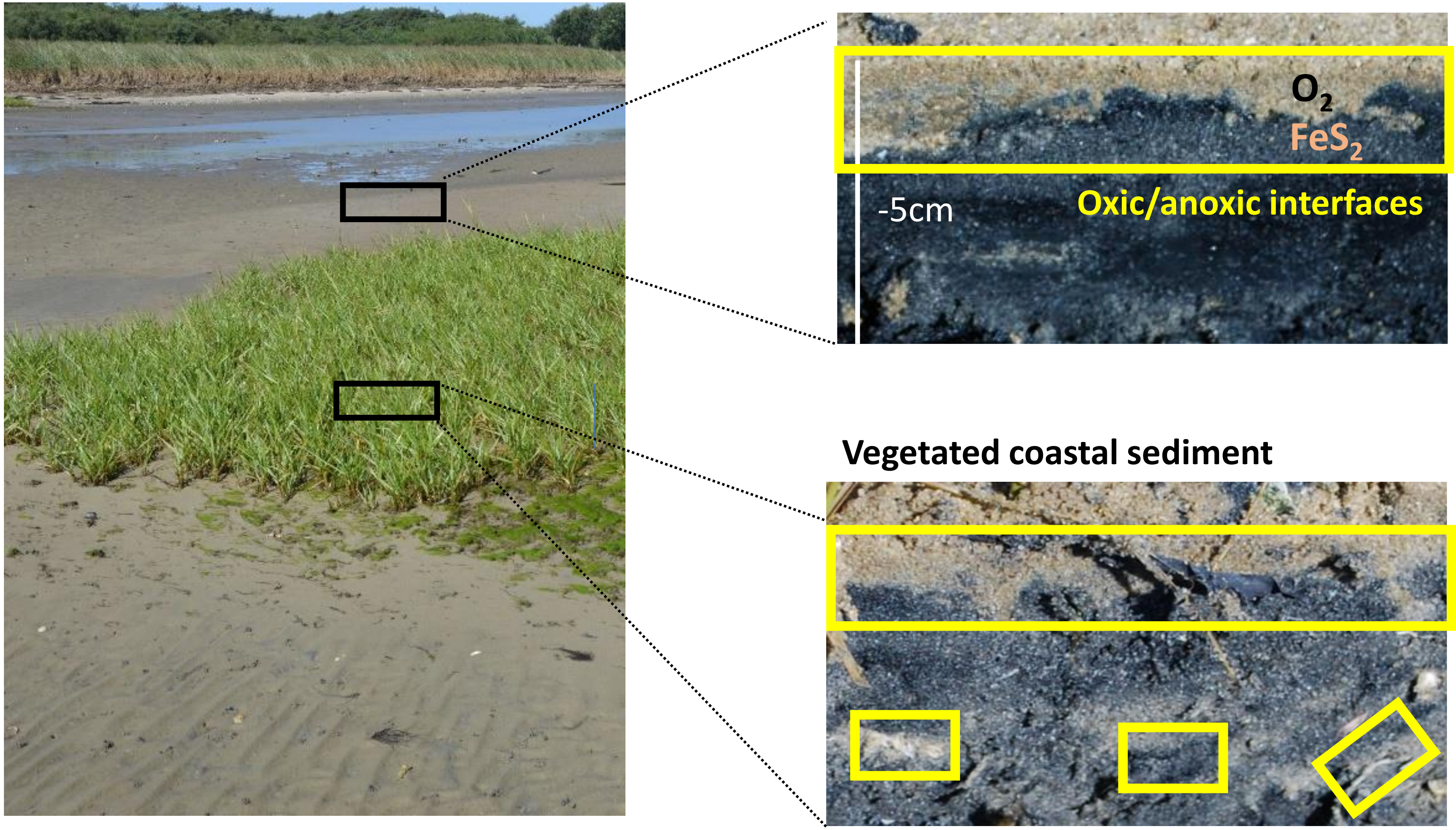
Sediment oxygenation in *Lobelia spp*

# Spatiotemporal heterogeneity controls important ecosystem functions

**Spartina patch – Wadden sea, Germany**

**Unvegetated coastal sediment**

**Vegetated coastal sediment**



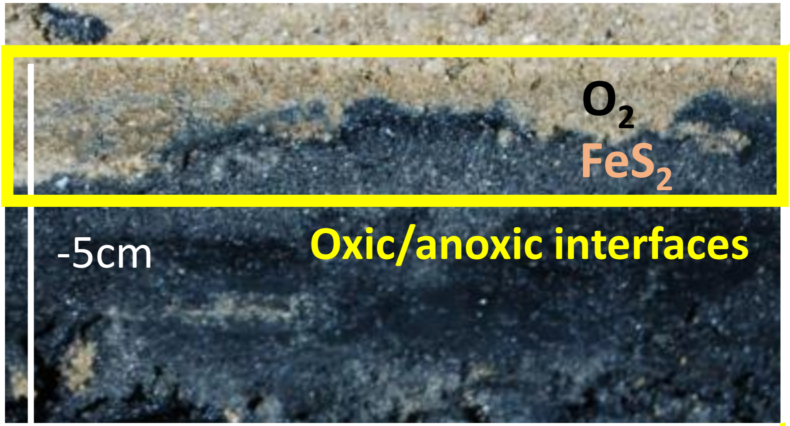
# Plant-mediated sediment oxygenation release oxygen into the rhizosphere

*Elymus athericus - Wadden sea marshes, Germany*

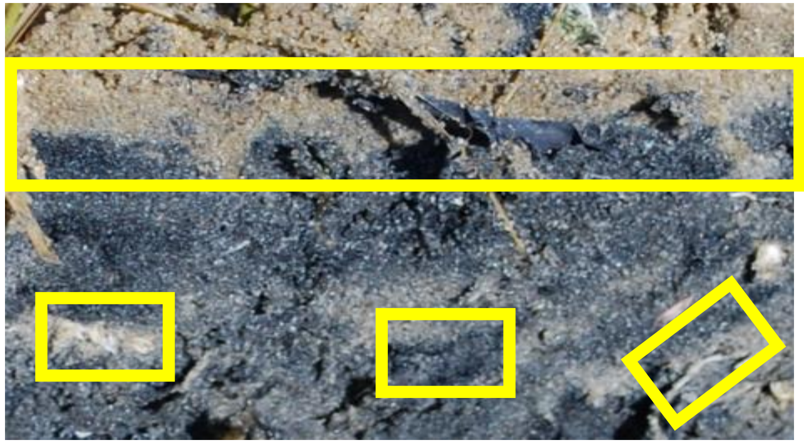

Koop-Jakobsen and Mueller (in review) Frontiers in plant science

# Spatiotemporal heterogeneity control important ecosystem functions

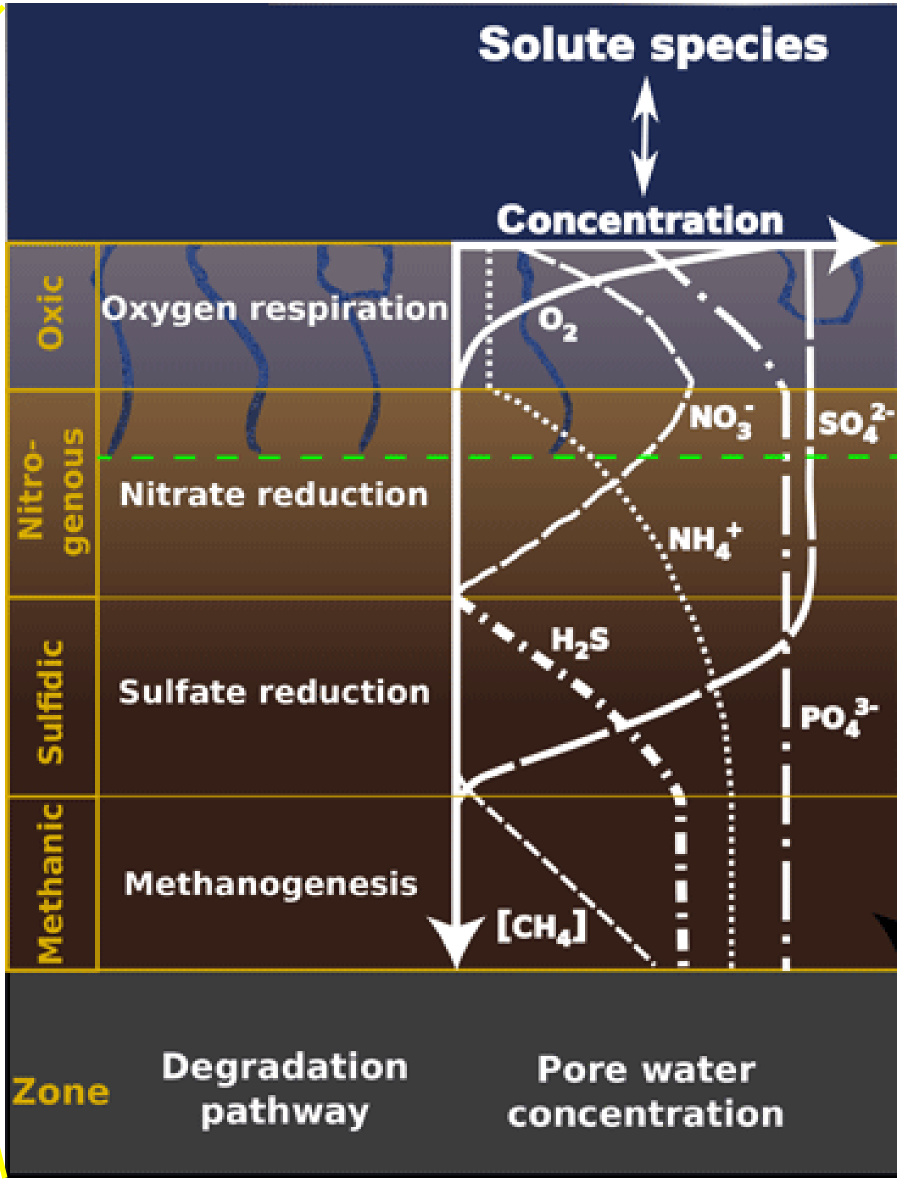
**Unvegetated coastal sediment**




**Vegetated coastal sediment**



## Diagenetic processes




Hülse et al Geosci. Model Dev., 11, 2649–2689, 2018

## Ecosystem functions

- Green house gas release
- Carbon turnover and sequestration
- Nutrient retention/turnover

# Nitrogen retension
# in Salt marsh rhizosphere

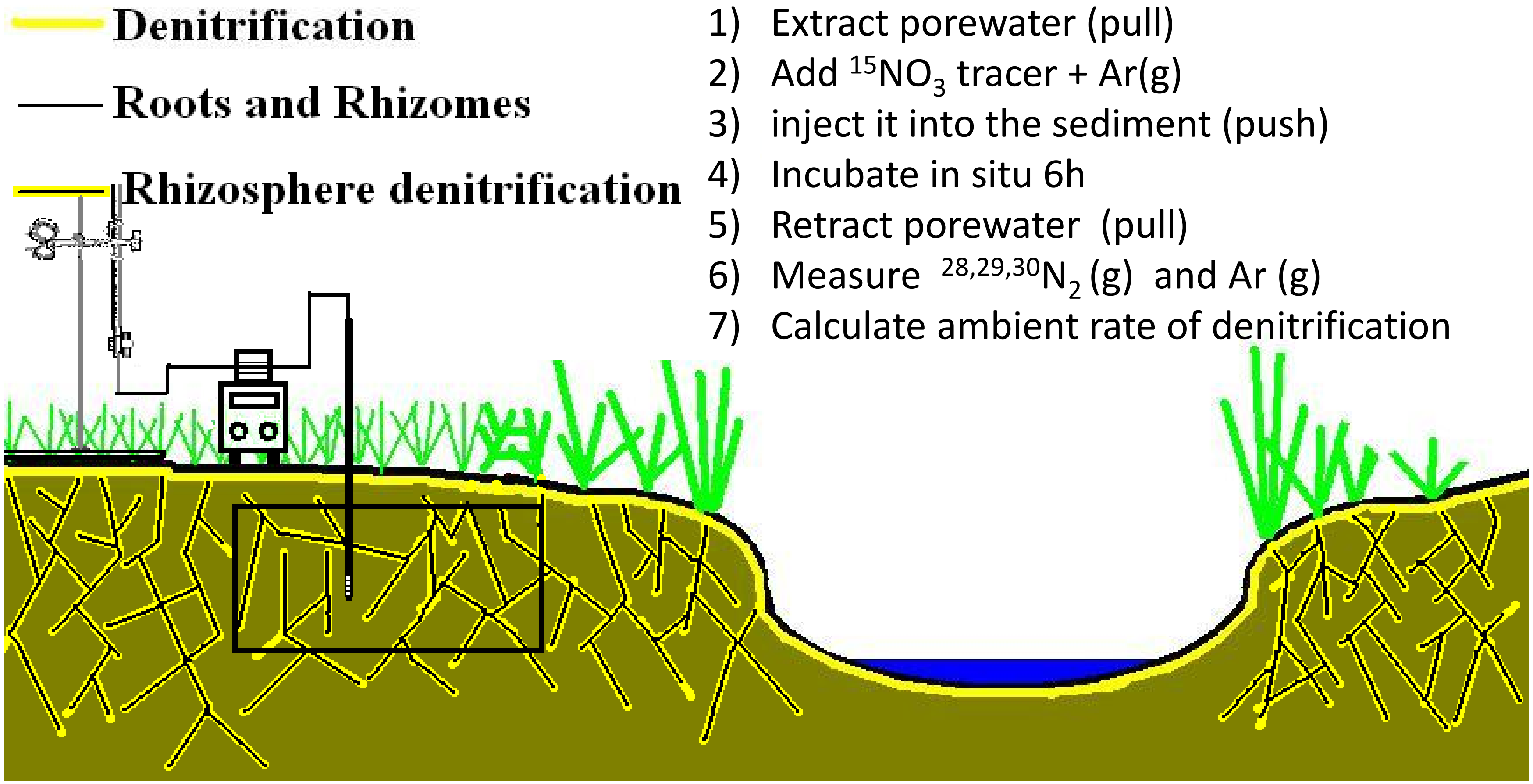
# Quantifying coupled nitrification-denitrification in marsh rhizospheres



- Salt marshes are important for coastal nitrogen retention
- Plant-mediated sediment oxygenation plays a key role for the nitrogen turnover
- The impact of plant-mediated sediment oxygenation was under-studied
- The role of rhizosphere denitrification was not quantified
- Measuring rhizosphere processes without disturbing biomass and sediment conditions is a challenge

# Measuring denitrification in a salt marsh rhizosphere

# - Combining Push Pull and isotope pairing techniques



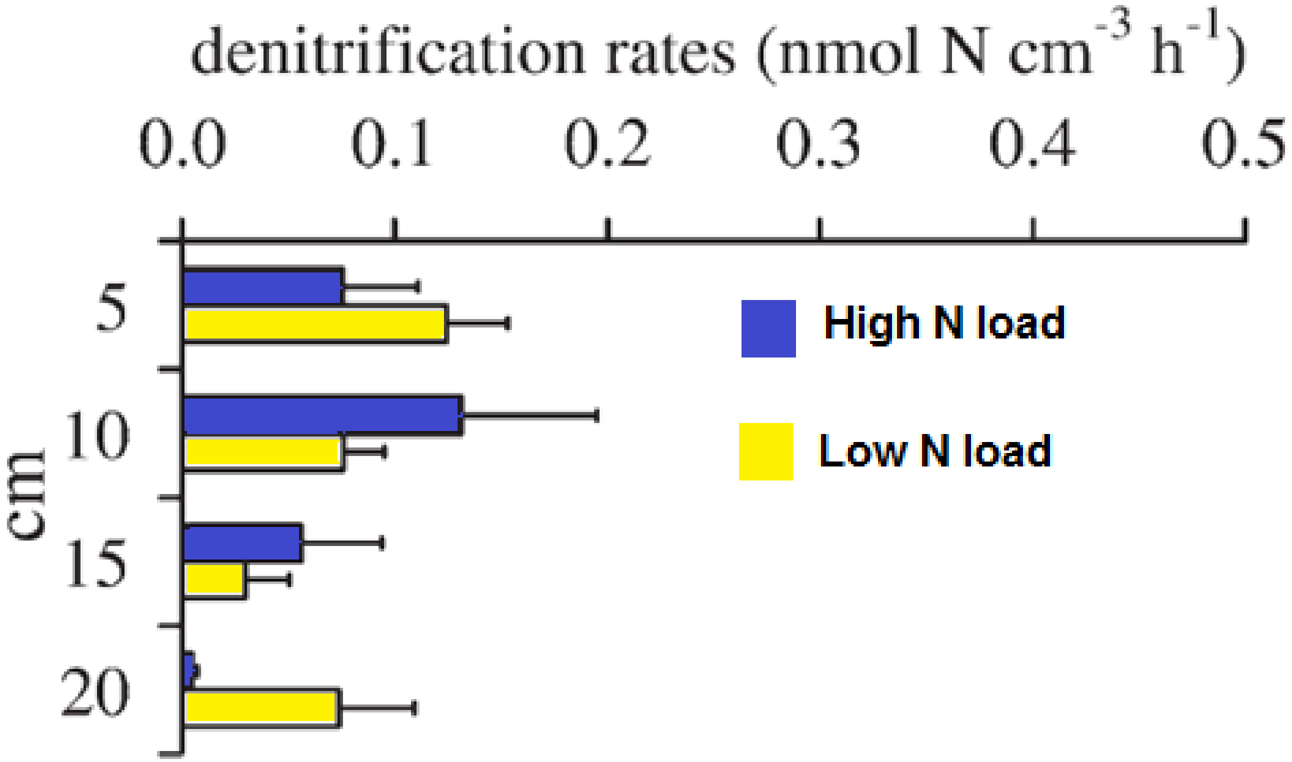

1) Extract porewater (pull)
2) Add $^{15}NO_3$ tracer + Ar(g)
3) inject it into the sediment (push)
4) Incubate in situ 6h
5) Retract porewater (pull)
6) Measure $^{28,29,30}N_2$ (g) and Ar (g)
7) Calculate ambient rate of denitrification

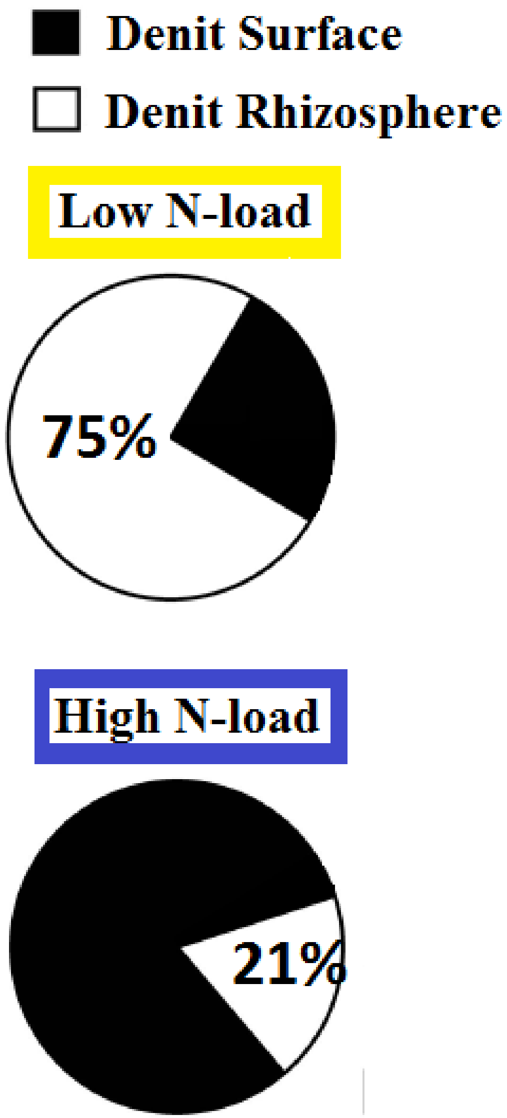
Koop-Jakobsen and Giblin (20009) - Limnology and Oceanography-Methods

# Coupled nitrification-denitrification in PIE marsh rhizospheres

Rhizosphere denitrification was quantified in the PIE marshes in fertilized and unfertilized marshes of the TIDE project.

Denitrification was measured down to 20cm

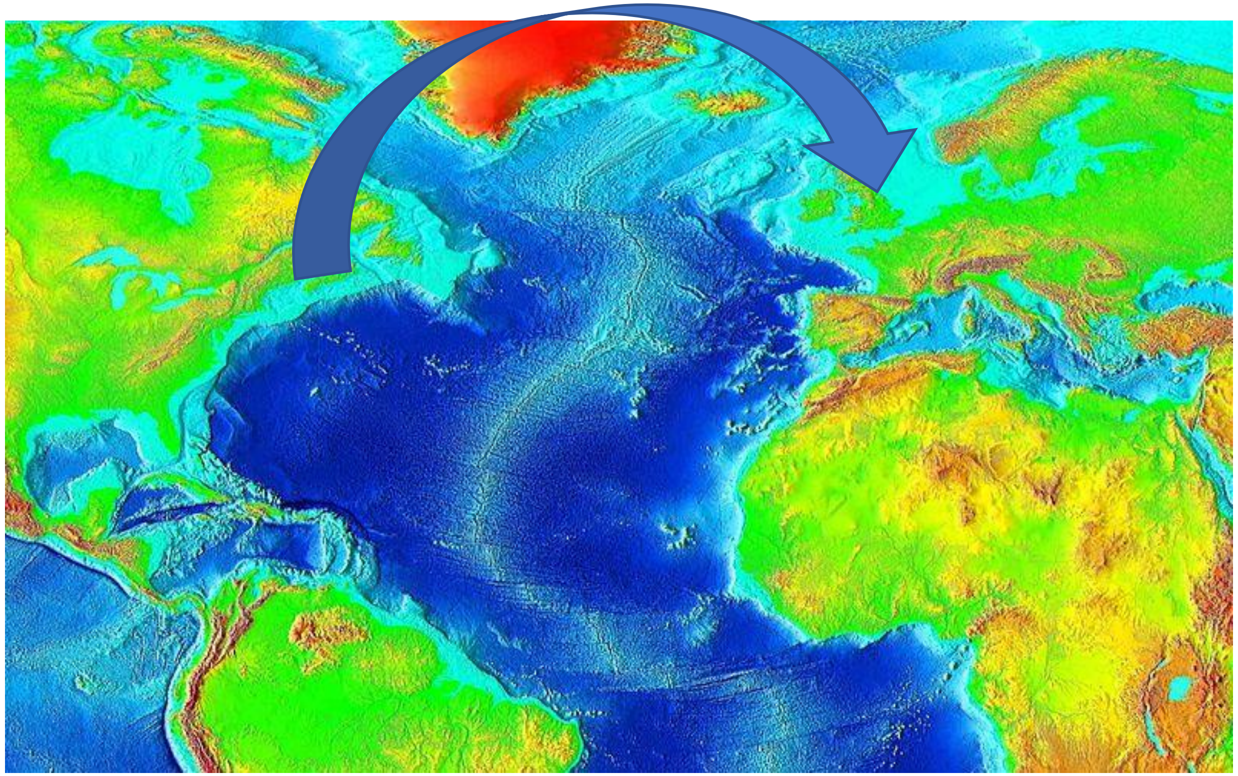

Koop-Jakobsen and Giblin (2010) - Limnology and Oceanography vol.55(2), pp789-802

# Spatial heterogeneity: Biomass structure

# The European *Spartina* story

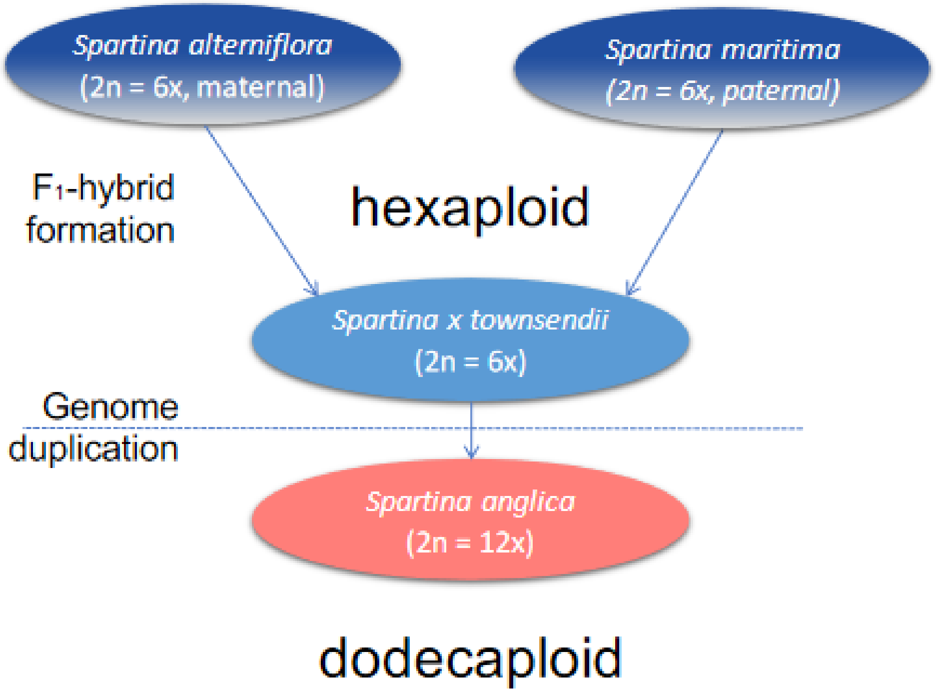
*Spartina alterniflora* was unintentionally introduced to England, probably by ballast water from North Atlantic transport around 1850.

*Spartina alterniflora* hybridized with the European native cordgrass Spartina maritima (small cordgrass) forming the naturally derived and sterile hybrid *Spartina × townsendii around 1870.*
*The fertile Spartina anglica* evolved by chromosome doubling out of *Spartina × townsendii* and was observed 25 years after the first appearance of this hybrid.



*Spartina alterniflora*

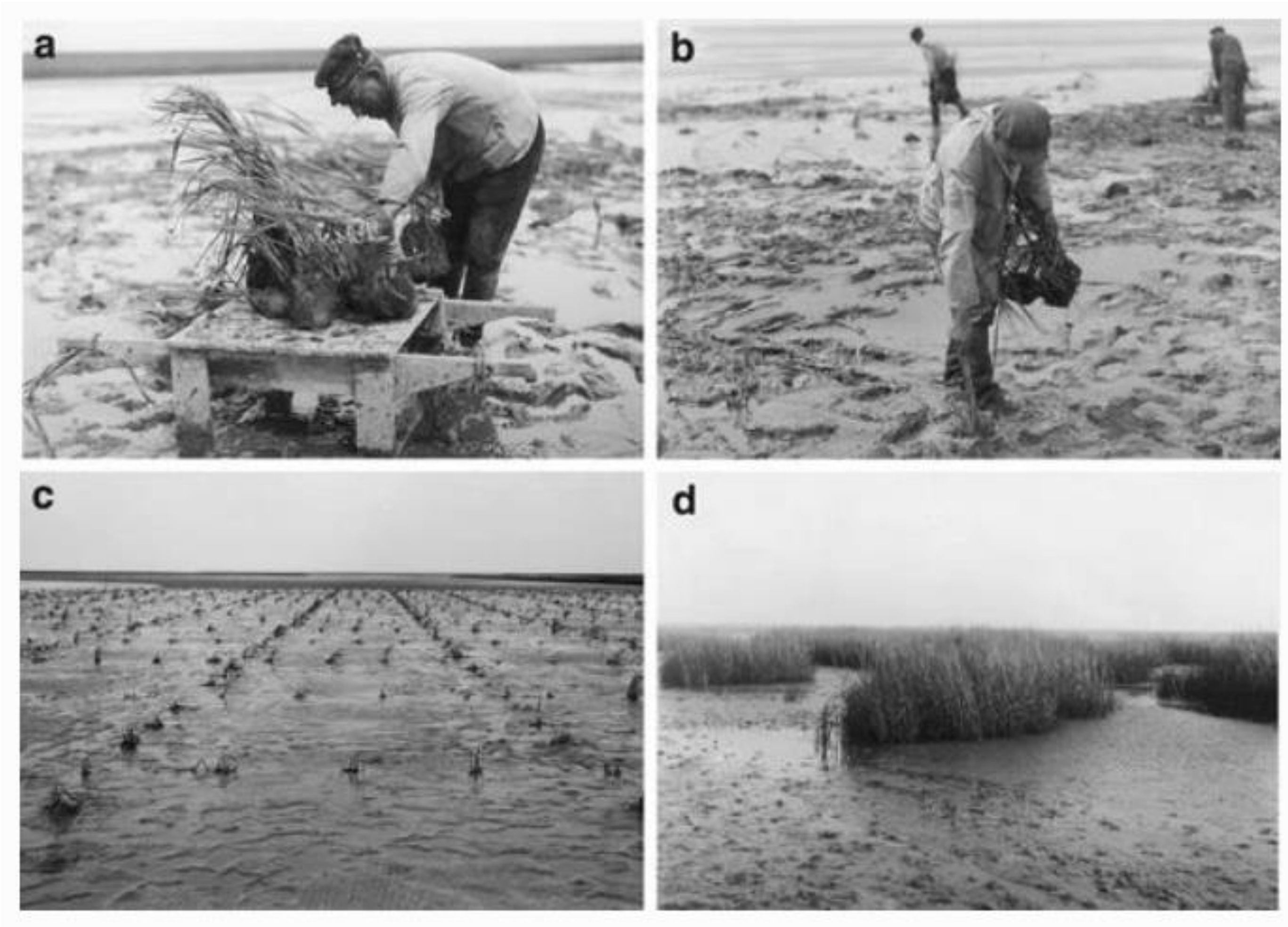
*Spartina maritima*



# The European *Spartina* story



**Spartina anglica was deliberately planted out along the Wadden sea for coastal protection**
**However, Spartina did not do established as well as expected until the last couple of decades**

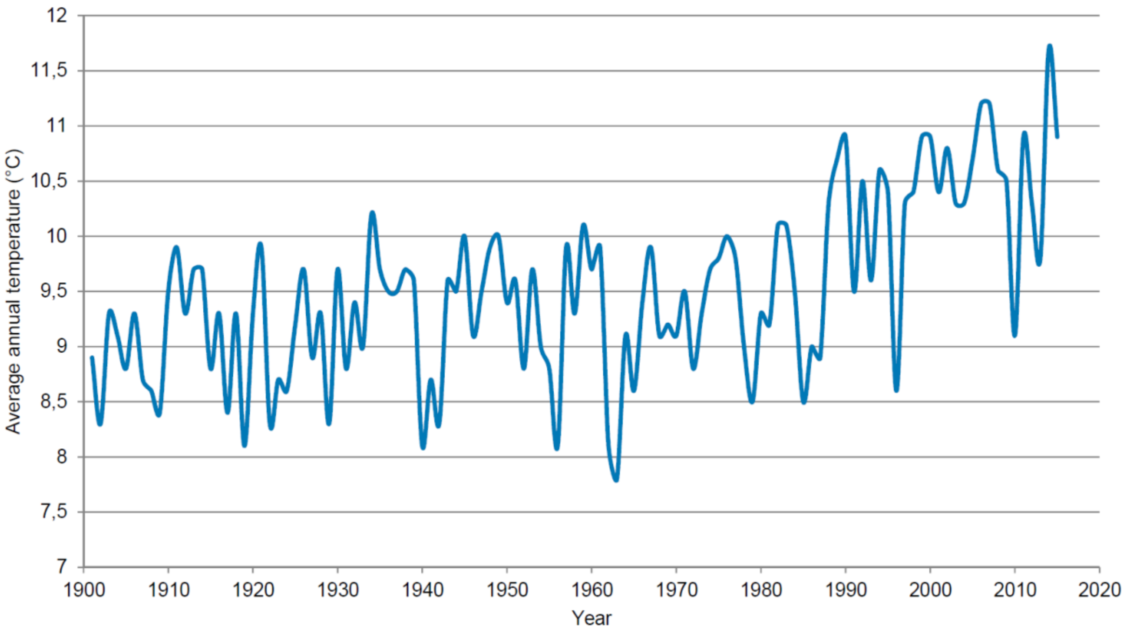




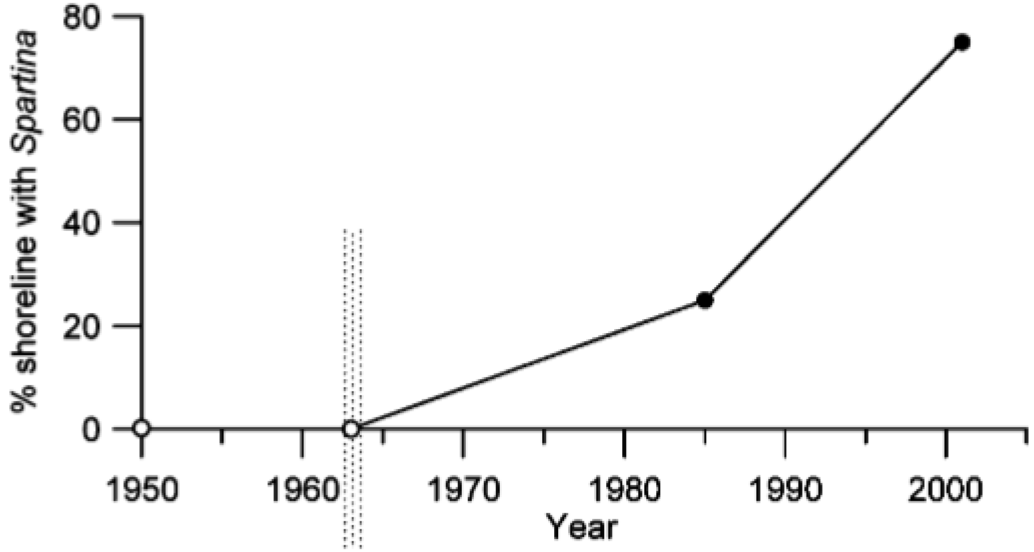
Nehring et al 2008

# The European *Spartina* story



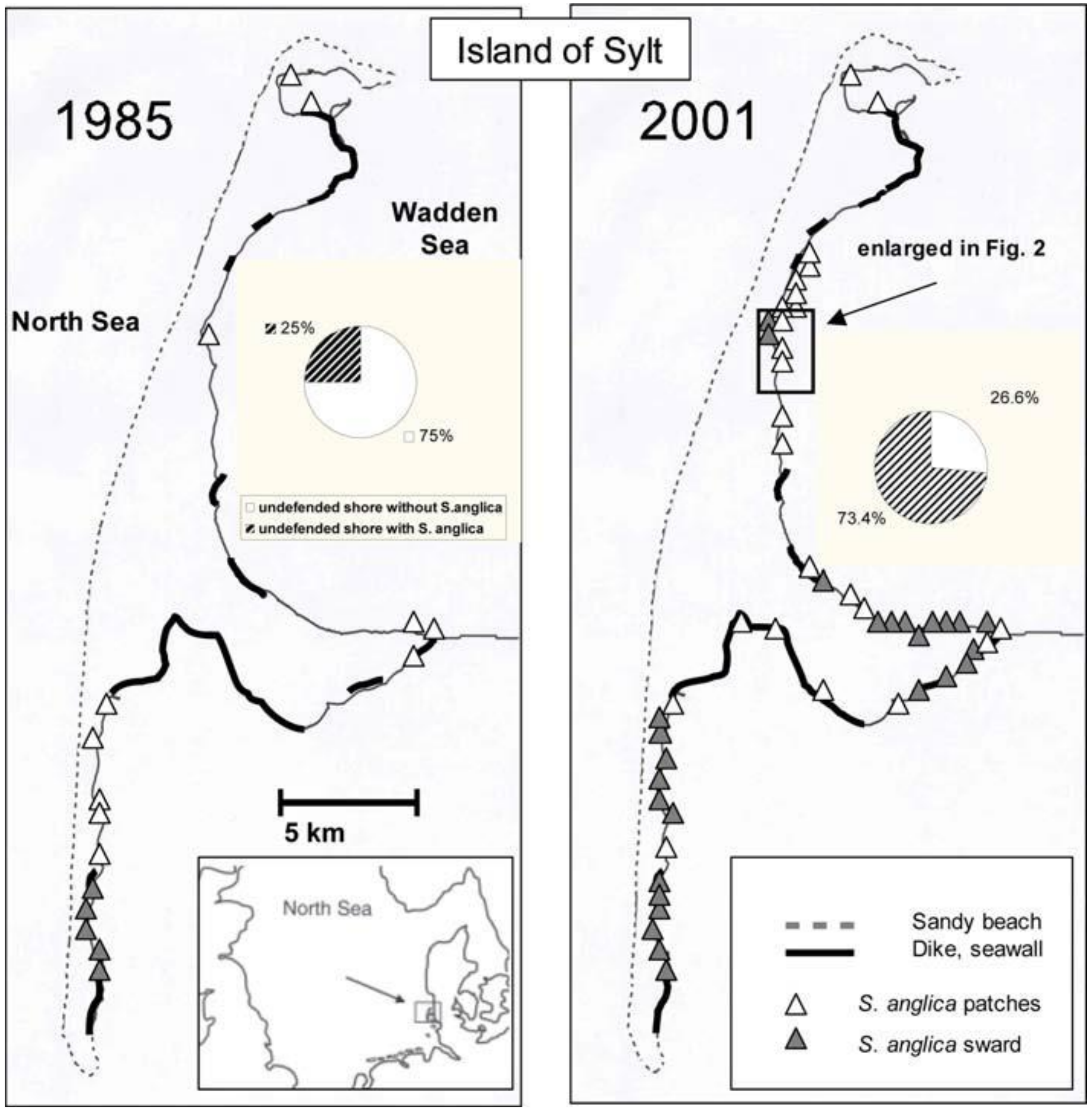



https://qsr.waddensea-worldheritage.org/reports/climate-change




Loebl et al 2006

**Spartina anglica is spreading in response to increased temperatures**




Loebl et al 2006

# The European – *Spartina* story

Since *S. anglica* was introduced by humans and it is now considered an alien invasive species.
In the highly protected area of the Wadden Sea, which is a national park and UNESCO heritage site, Spartina is no longer welcome.

Spartina out competing Salicornia , Nehring et al 2008

# Morphology of Spartina rhizospheres – structure

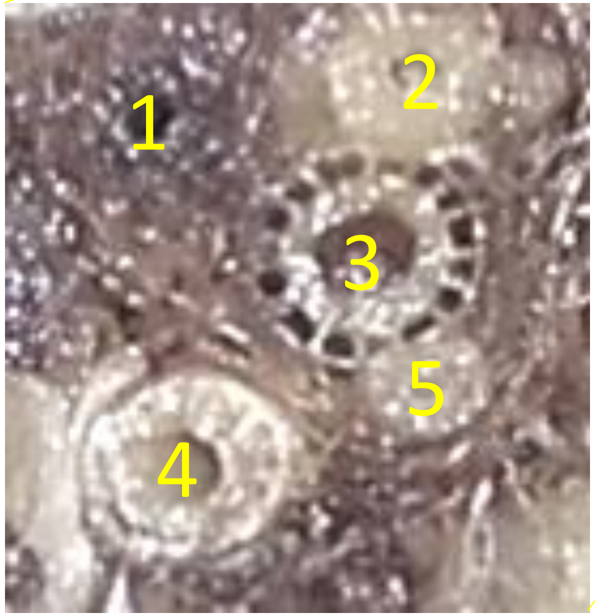
20cm

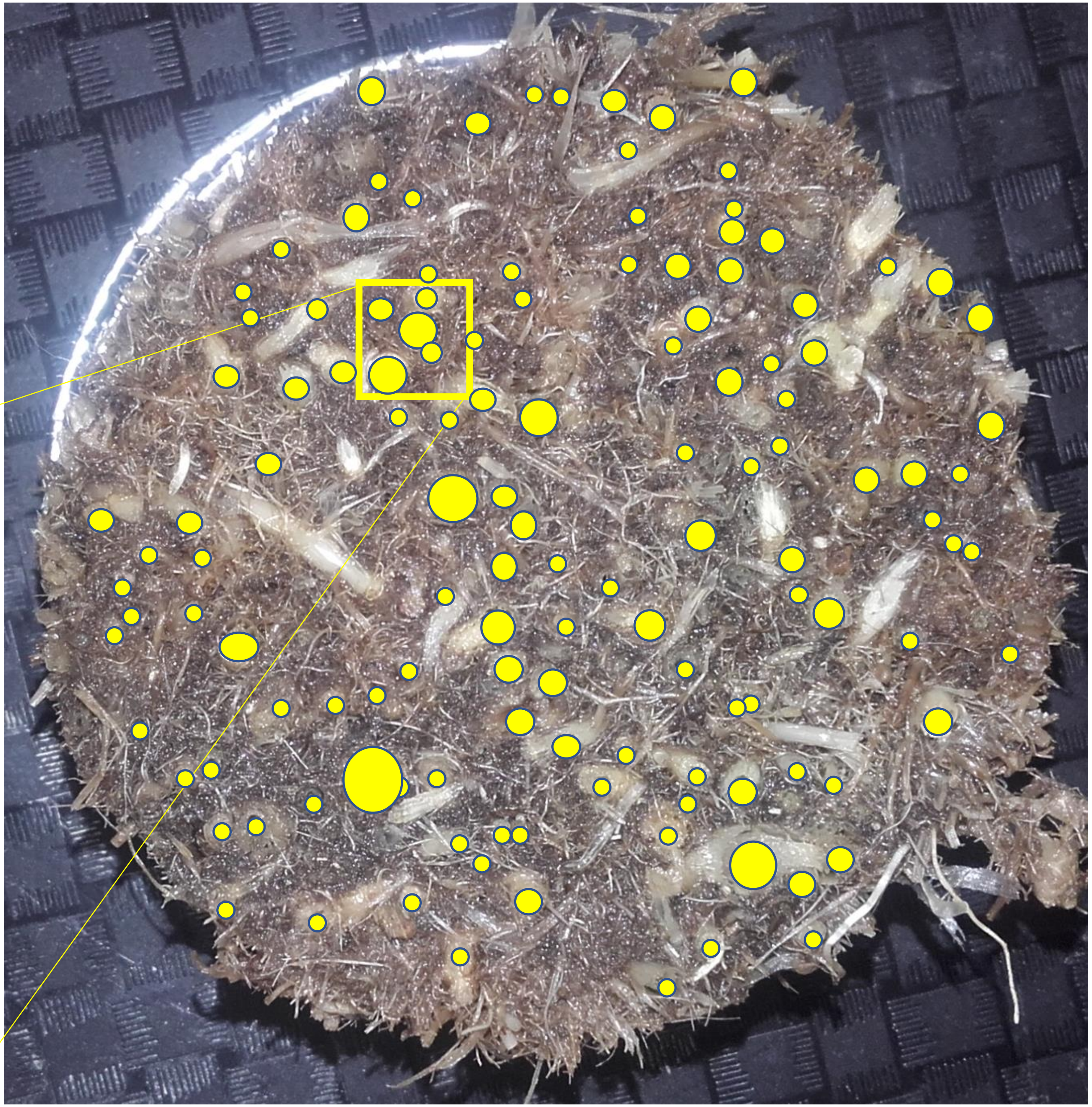
Structural heterogeneity: Biomass

# Wetland plant rhizosphere


143 rhizomes with aerenchyma in cross section

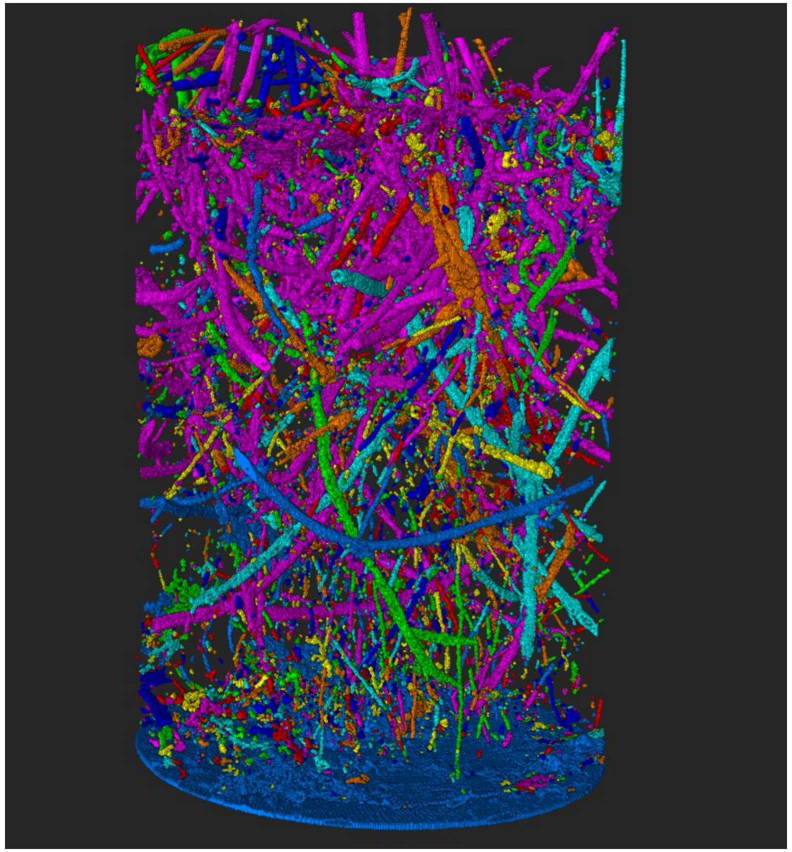
~6000 rhizomes with aerenchyma per $m^{-2}$ at -5 cm depth



Structural heterogeneity: Biomass

# Spatial heterogeneity in European marshes - Biomass structure



**First attempt ….Koop-Jakobsen… 2017**

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**Granse, Titschlack, Ainouche, Jensen and Koop-Jakobsen "*Subsurface aeration of tidal wetland soils: root-system structure and aerenchyma connectivity in Spartina (Poaceae)*" In review STOTEN 2021**

# Spartina rhizosphere – biomass structure

**In the Wadden sea Salt marshes there are two types of Spartina hybrids:**

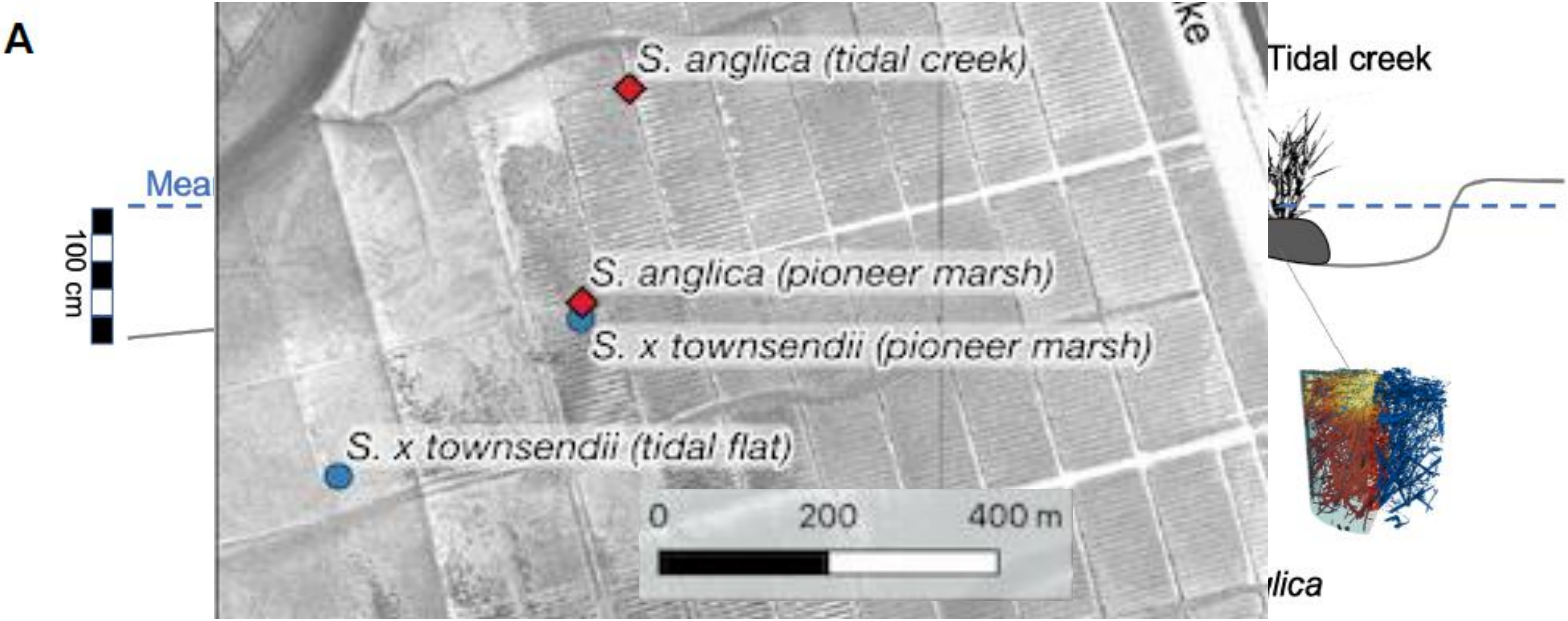
- ***Spartina townsendii*** **(hexaploid)**
- ***Spartina anglica*** **(dodecaploid)**

**Chromosome doubling during the hybridization process is known to result structural changes in particular large aerenchyma formation.**

**Aerenchyma formation is often associated with high gas-transport capability. High connectivity of the aerenchym the prerequisite**

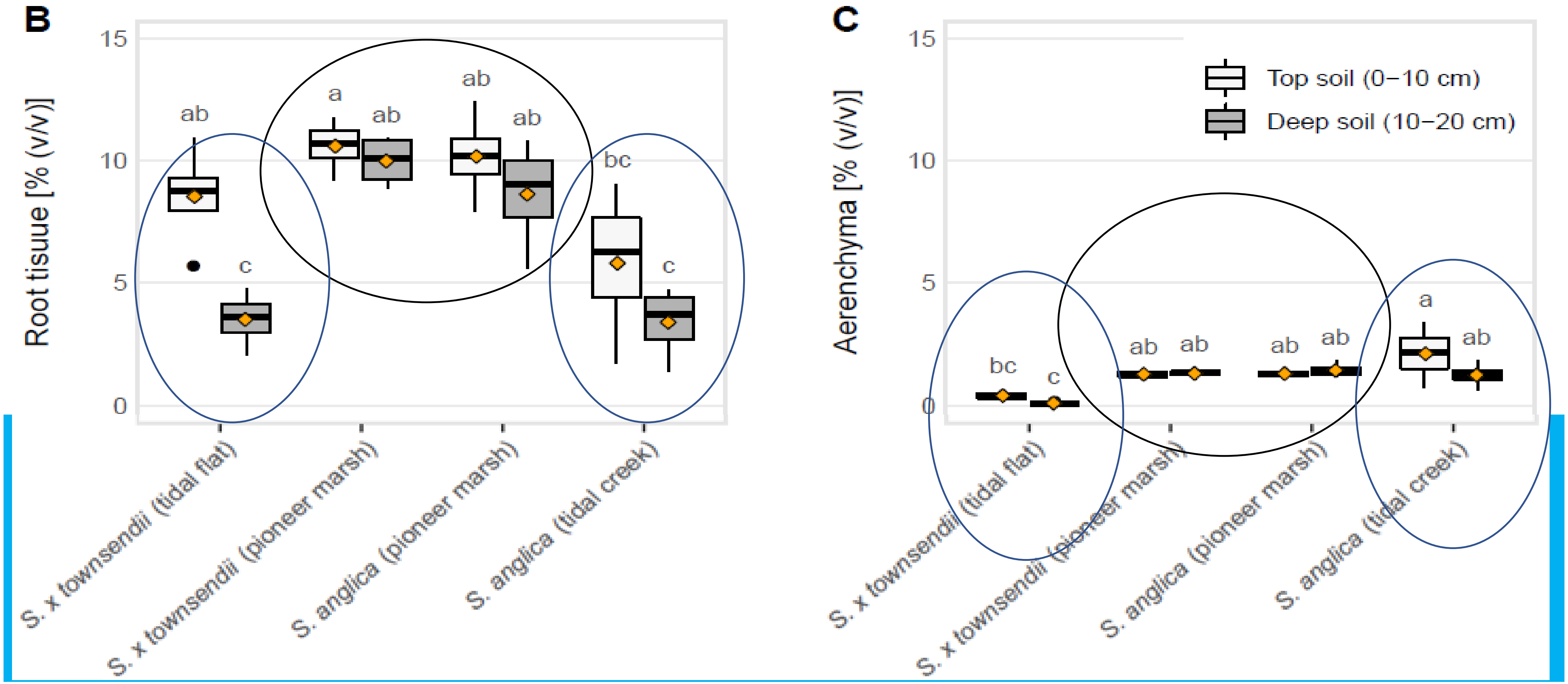
# Plant-mediated sediment oxygenation

# Plant-mediated sediment oxygenation




Granse, Koop-Jakobsen (in review) STOTEN

# Belowground biomass volume and aerenchyma volume



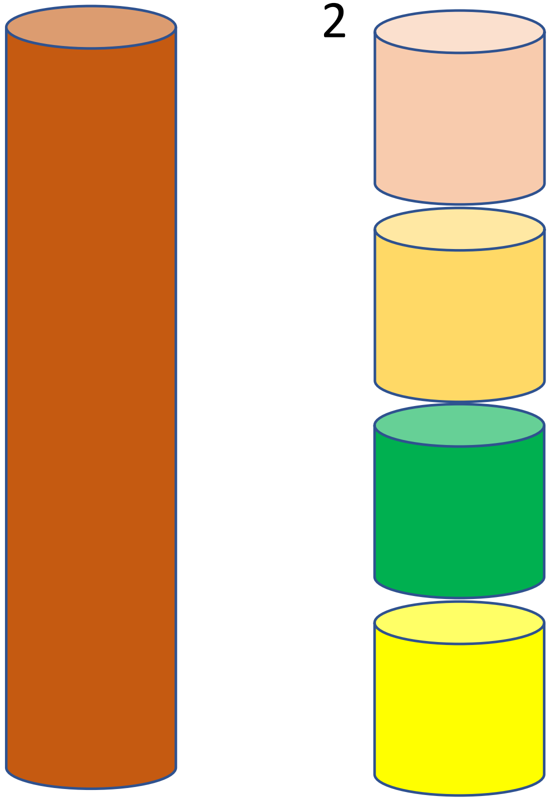

Granse, Koop-Jakobsen et al in review STOTEN 2021

Structural heterogeneity: Biomass

# Connectivity Analysis

## Fragmentation and connectivity

Rhizome system 1 Rhizome system 2



Low Fragmentation
High Connectivity

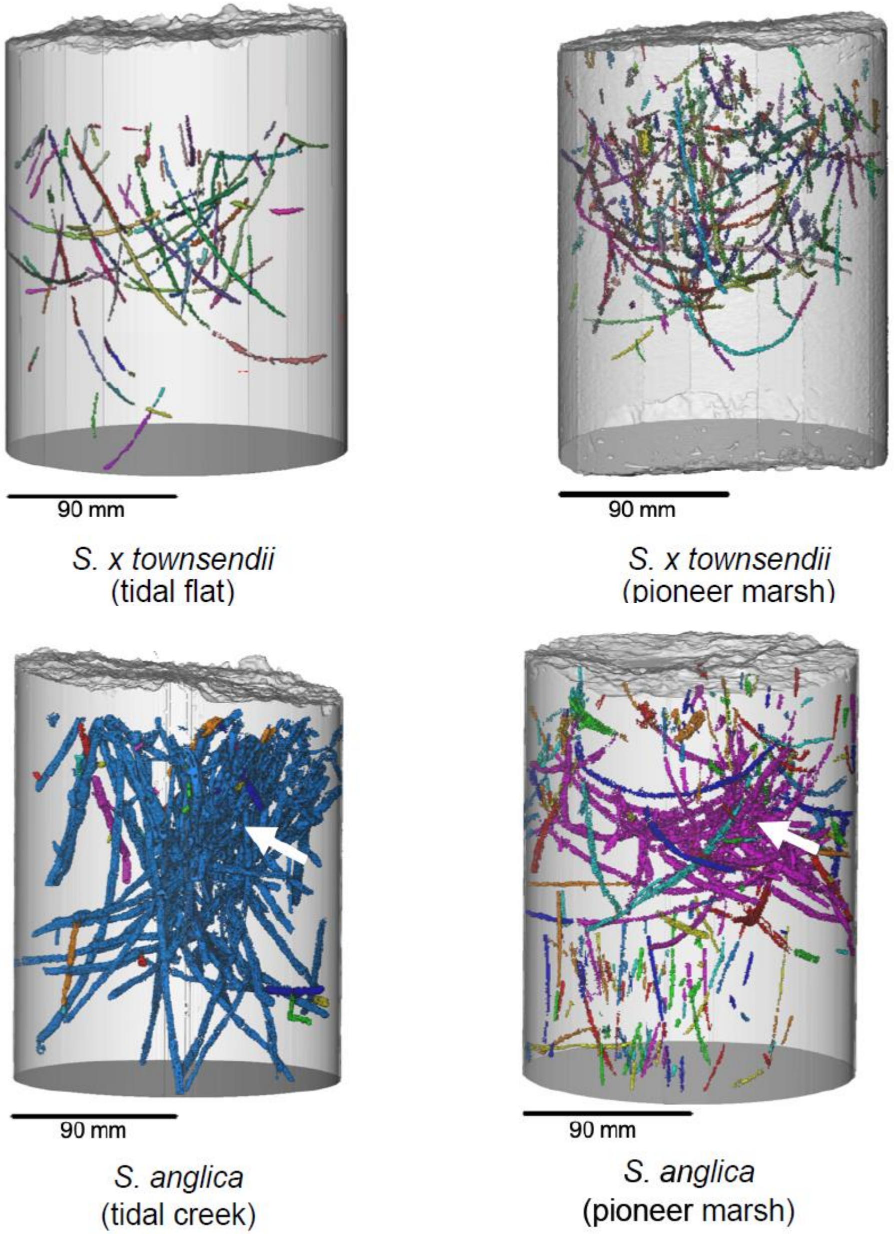
High Fragmentation
Low Connectivity

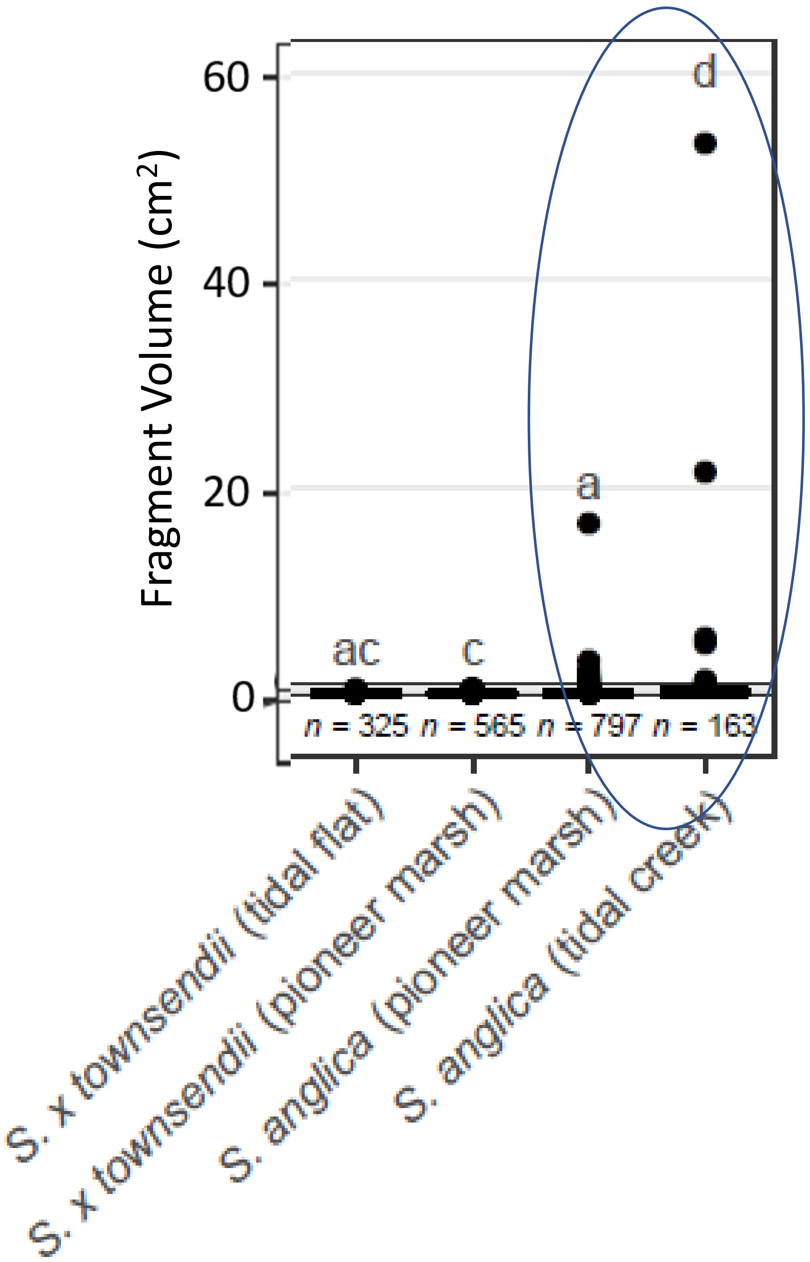
## Root systems structure and gas transport

Oxygen translocation from aboveground sources to roots and rhizomes require an unbroken aerenchyma compartment from the stems to roots.

CT-scanning was used to detect rhizome connectivity  targeting larger rhizomes with a minimum diameter of 1.4 mm and 70 mm in length.

Fragmentation and connectivity



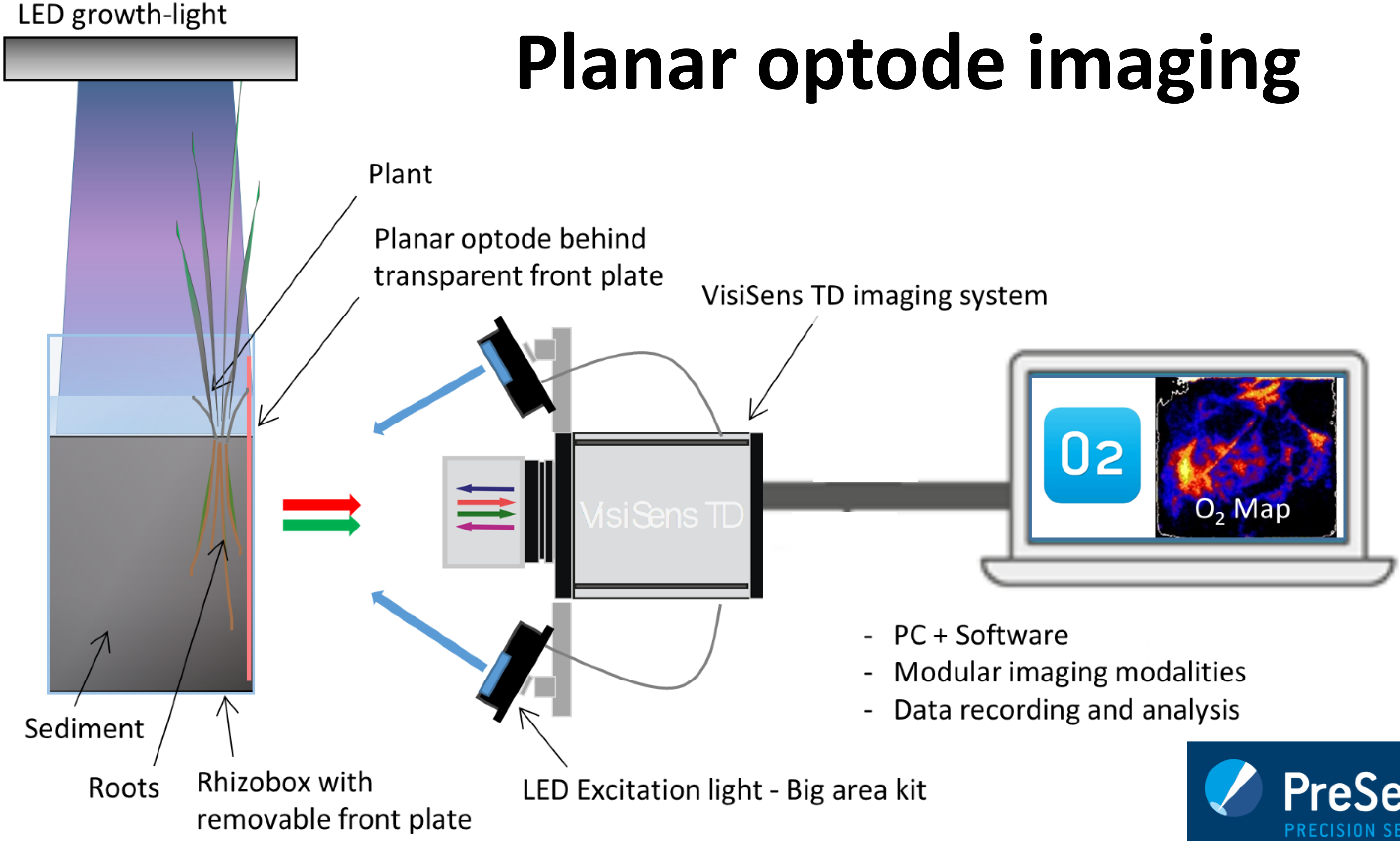

Granse, Koop-Jakobsen (in review) STOTEN

Structural heterogeneity: Biomass

# Spatiotemporal heterogeneity: Plant-mediated sediment oxygenation *Spartina anglica*

# Planar optode imaging

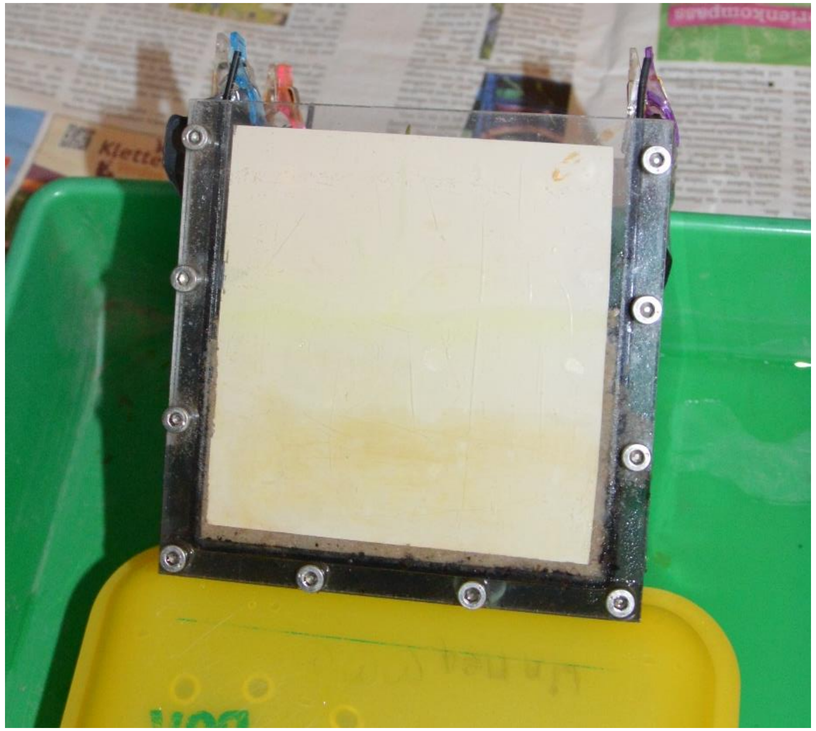





- PC + Software
- Modular imaging modalities
- Data recording and analysis

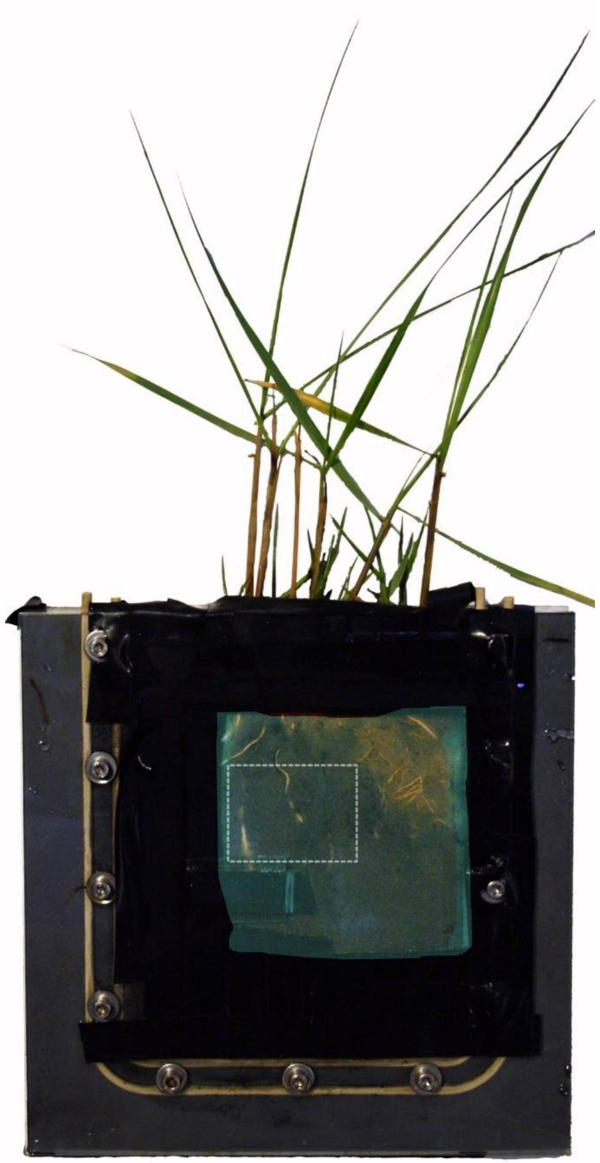
PreSens
PRECISION SENSING

# Prepairing rhizobox

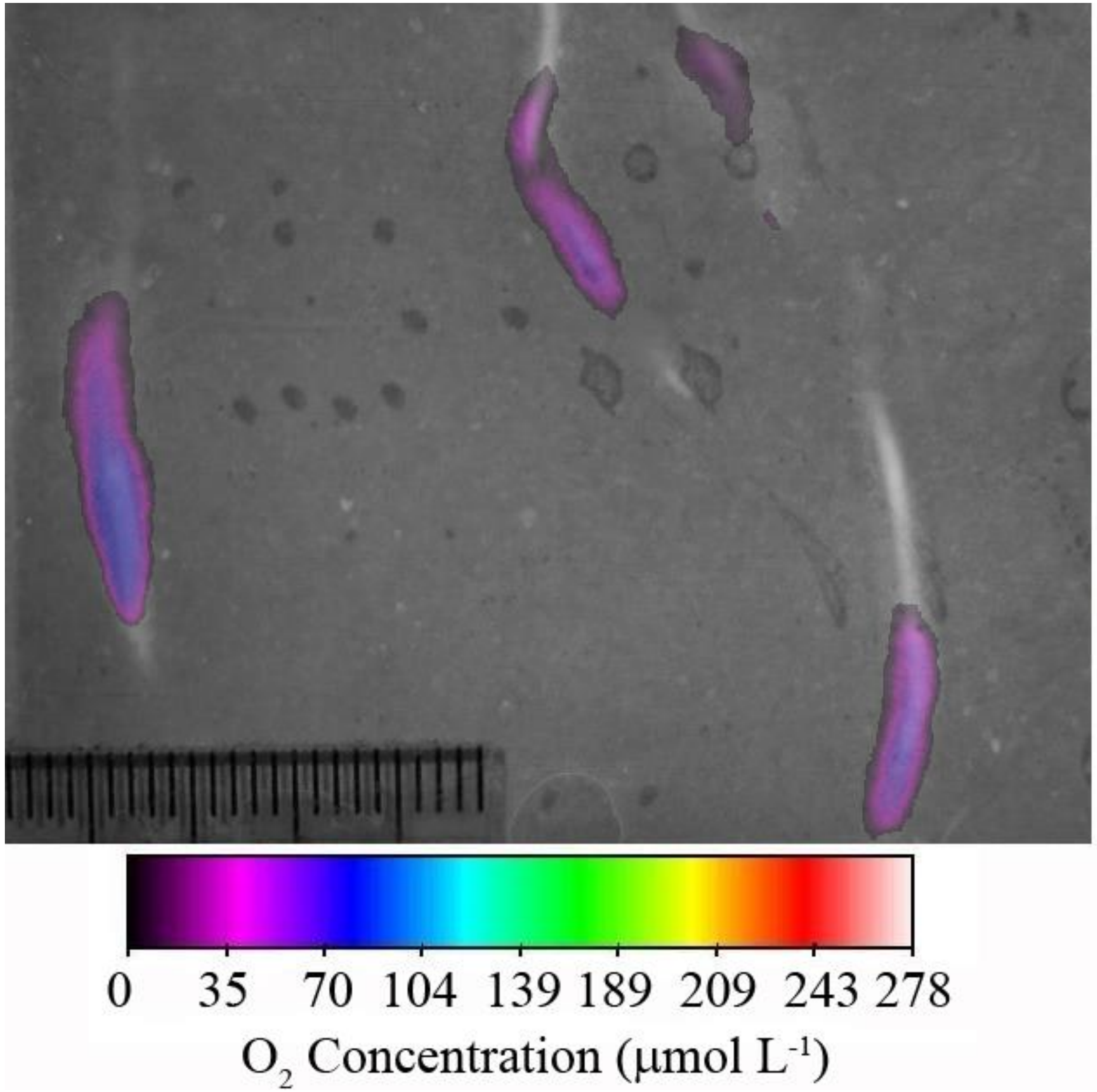


# Rhizosphere $O_2$-dynamics studied by Planar Optode



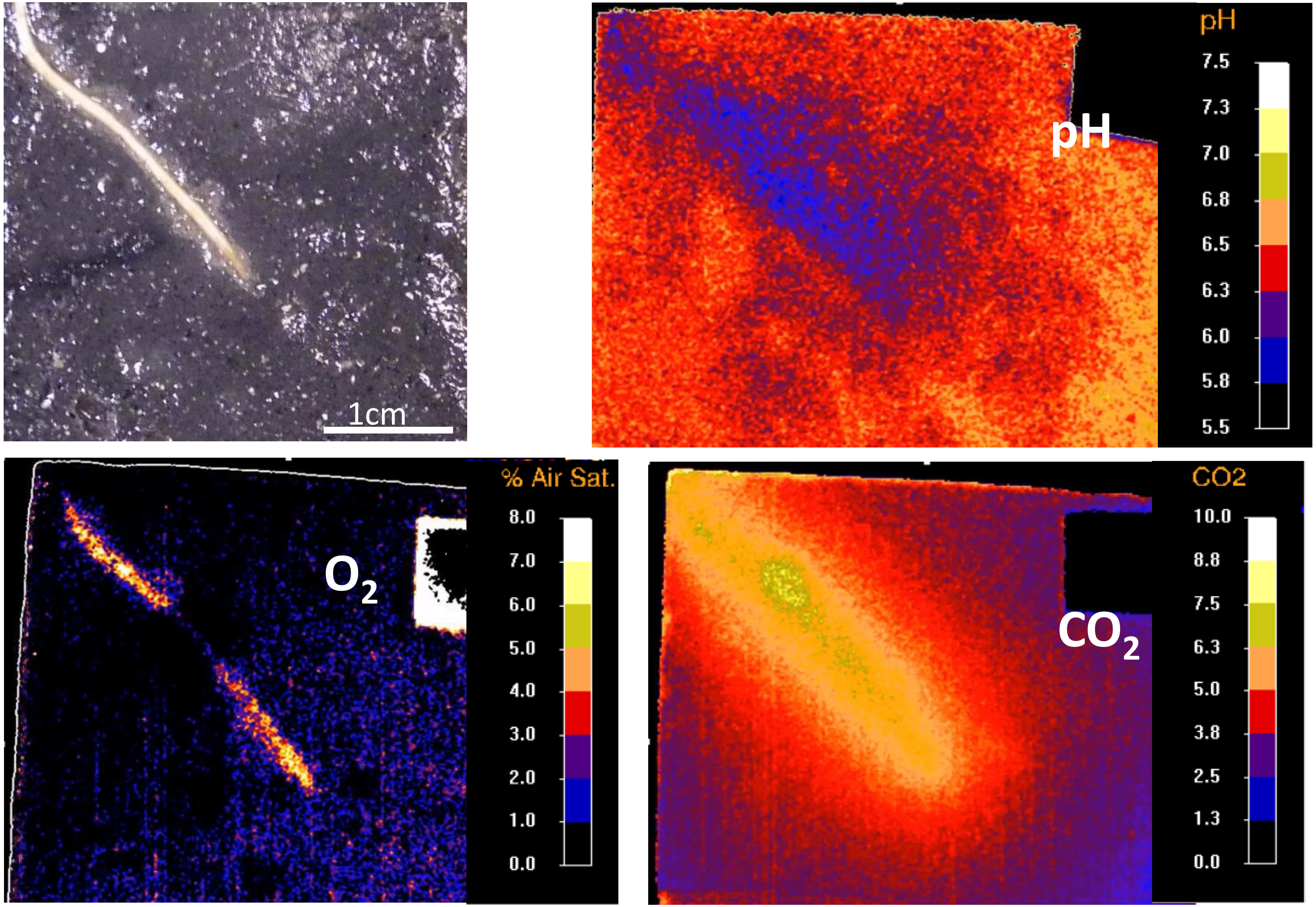


Rhizobox with S. anglica roots




Koop-Jakobsen et al 2015 Estuaries and coast

# Dynamics of $O_2$, pH and $CO_2$ in marsh rhizospheres




Plant-mediated sediment oxygenation

Koop-Jakobsen et al 2018 Frontiers in Plant science

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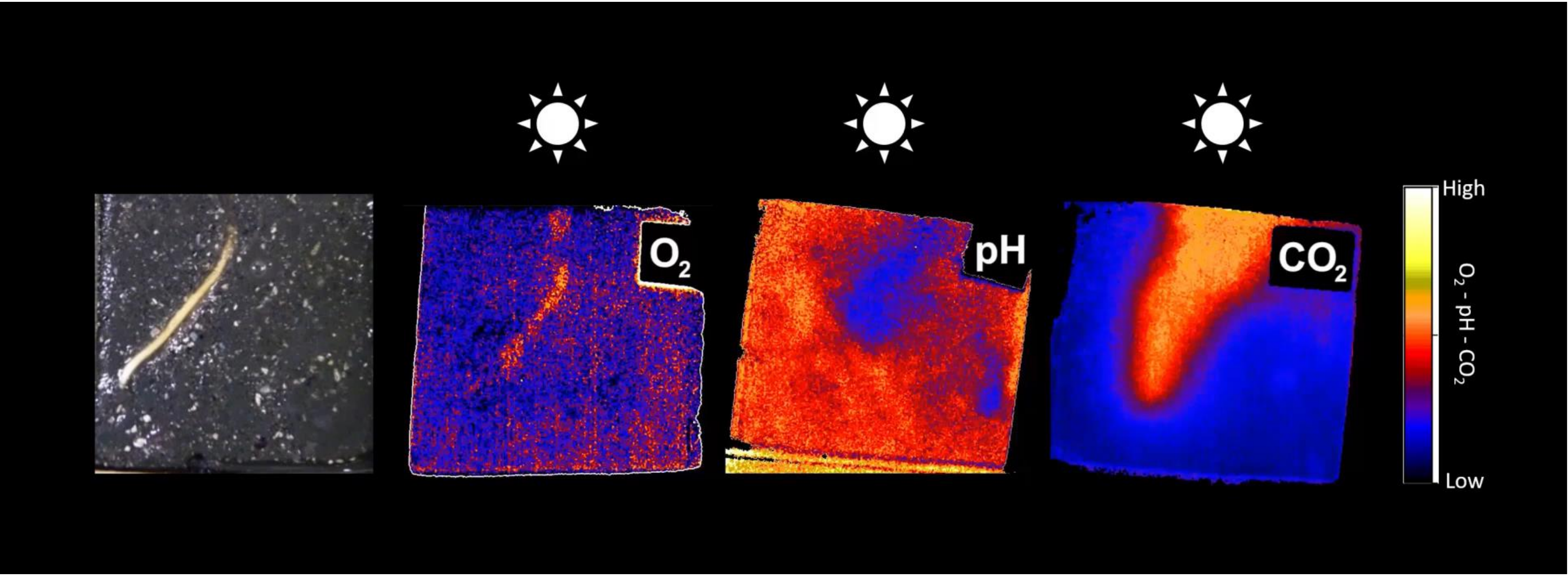
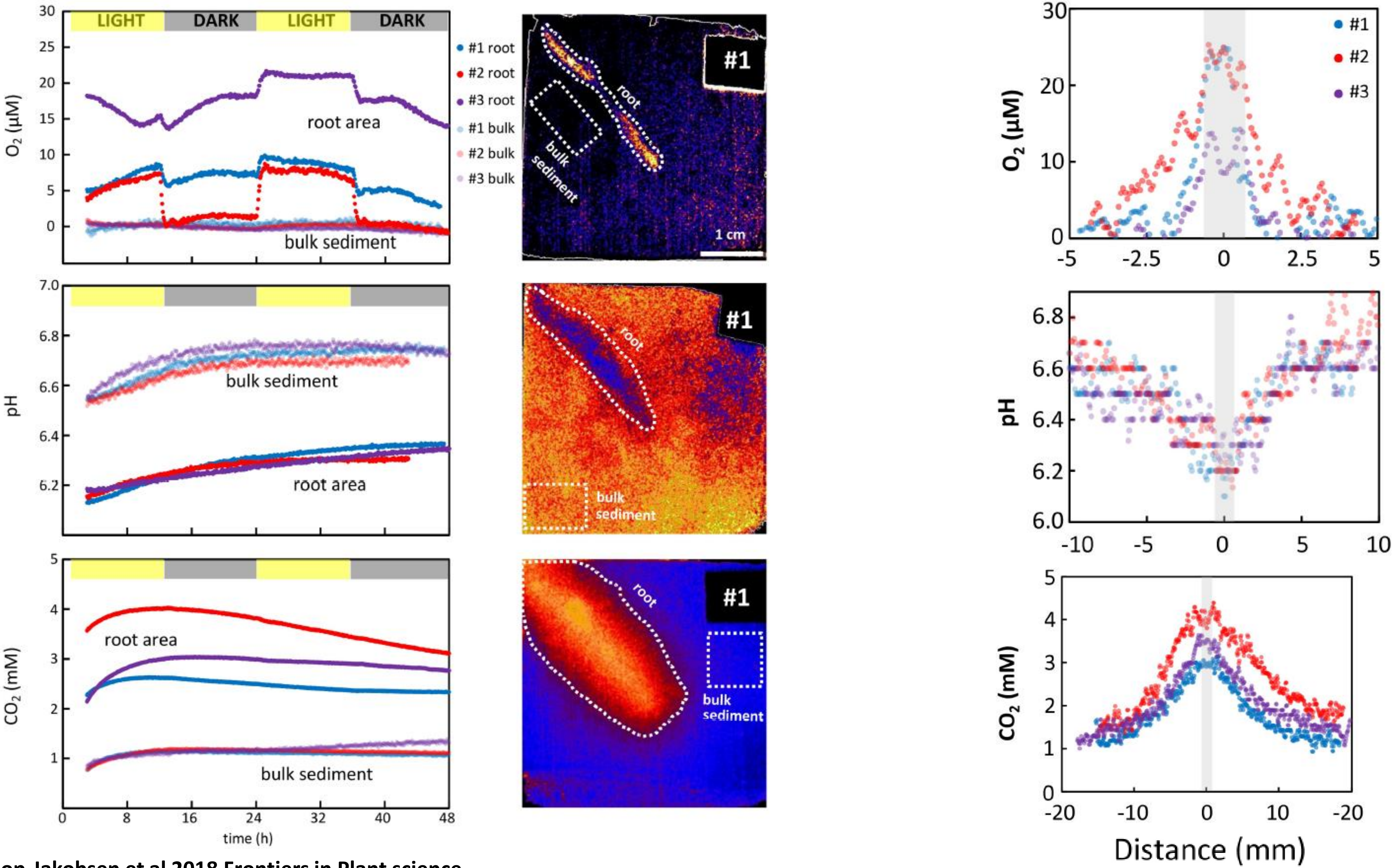



Daily variation in $O_2$, pH and $CO_2$ around Spartina root. (periods: 12h light/ 12h dark)

Koop-Jakobsen et al 2018 Frontiers in Plant science

# Plant-mediated sediment oxygenation




Koop-Jakobsen et al 2018 Frontiers in Plant science

# Oxygen and $CO_2$ dynamics in *Cyperus difformis*



**Are plant-mediated sediment oxygenation and Root-mediated $CO_2$ uptake key flood-adaptive traits in *Cyperus difformis?***


Photo from http://www.knowledgebank.irri.org/decision-tools/rice-doctor/rice-doctor-fact-sheets/item/flooding-or-submergence