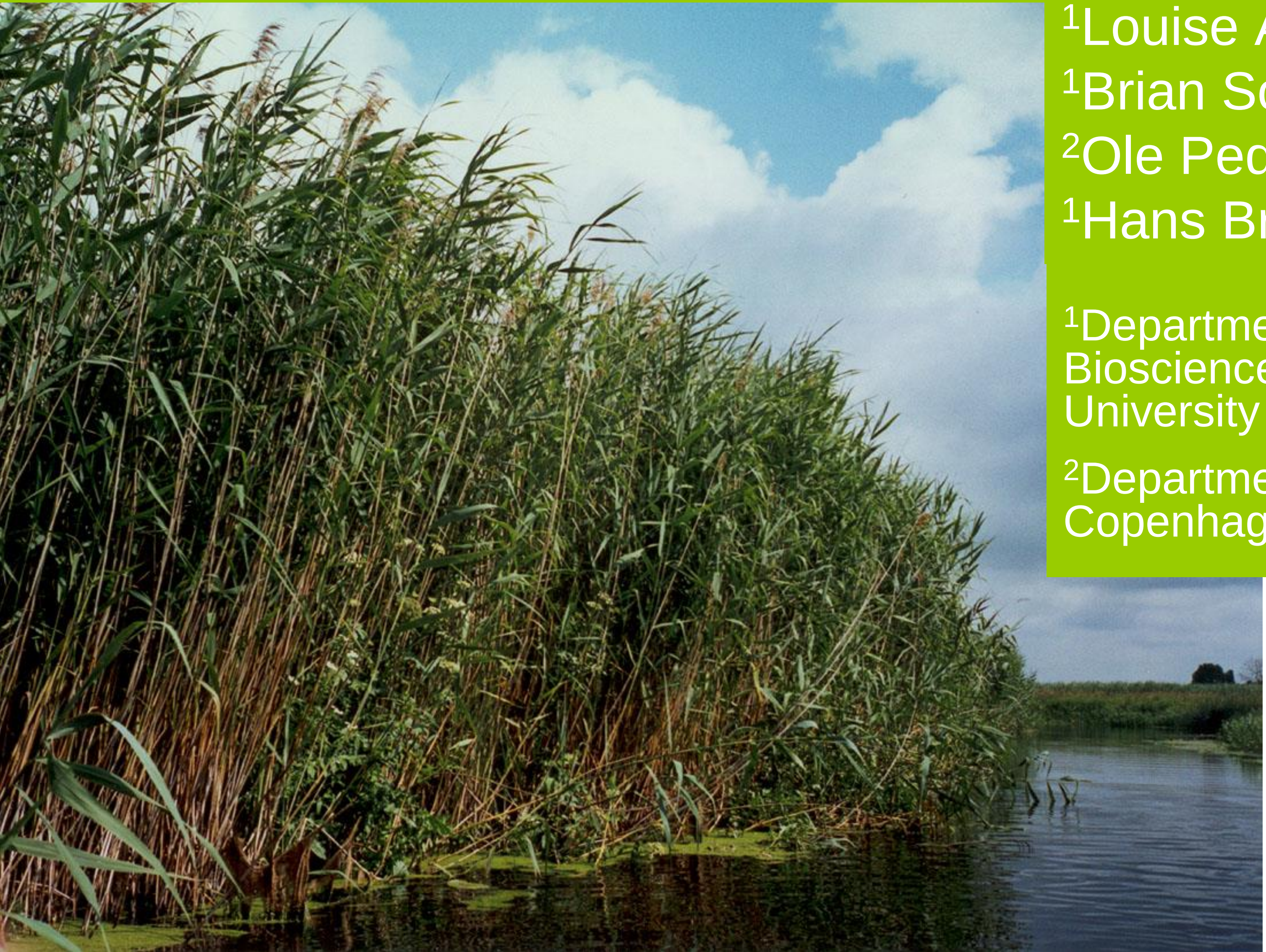
Phragmites snorkelling: how does it survive water level fluctuations?



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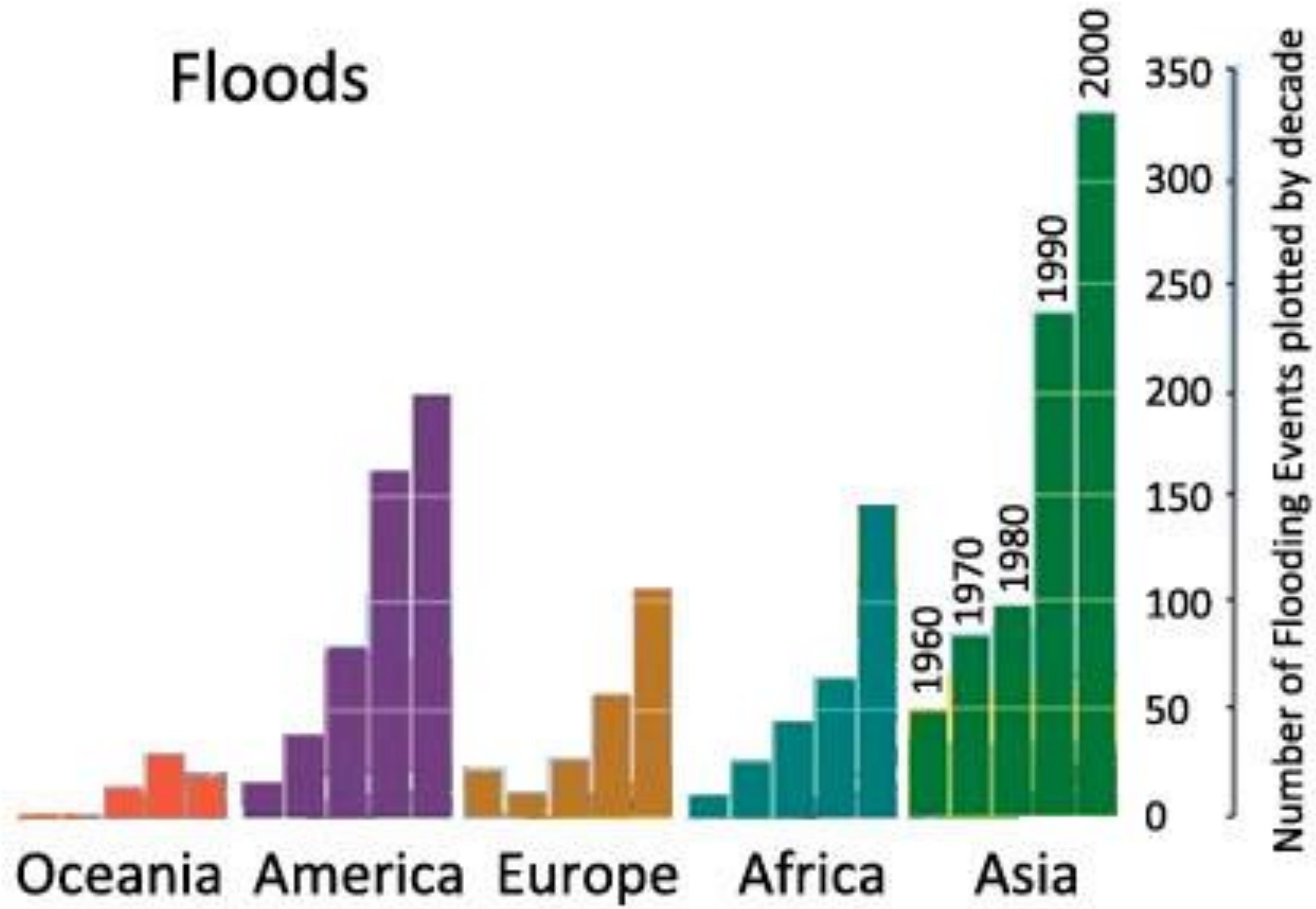
Introduction:

Floods are becoming more frequent due to climate change: Wetlands are being subject to more frequent inundations and larger water level fluctuations.

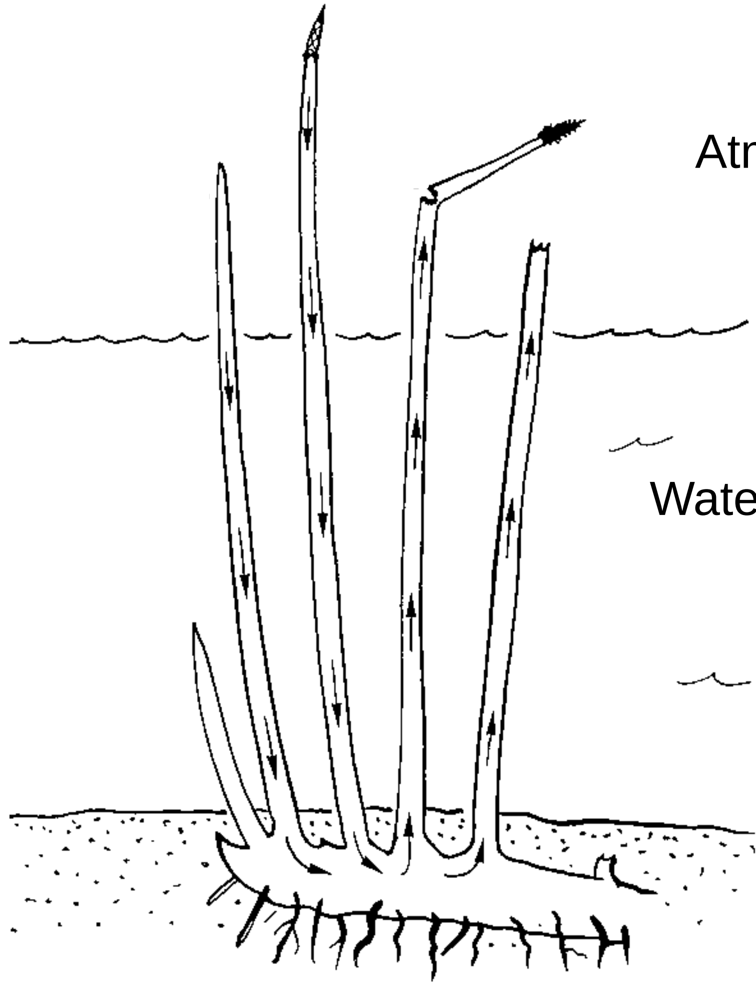


Source: http://maps.grida.no/go/graphic/number-of-flood-events-by-continent-and-decade-since-1950

- **Introduction:**
- Flooding tolerance: The adaptations that allow plants (aerobic organisms) to live where there is little or no oxygen.

- Oxygen deprivation is the key problem.

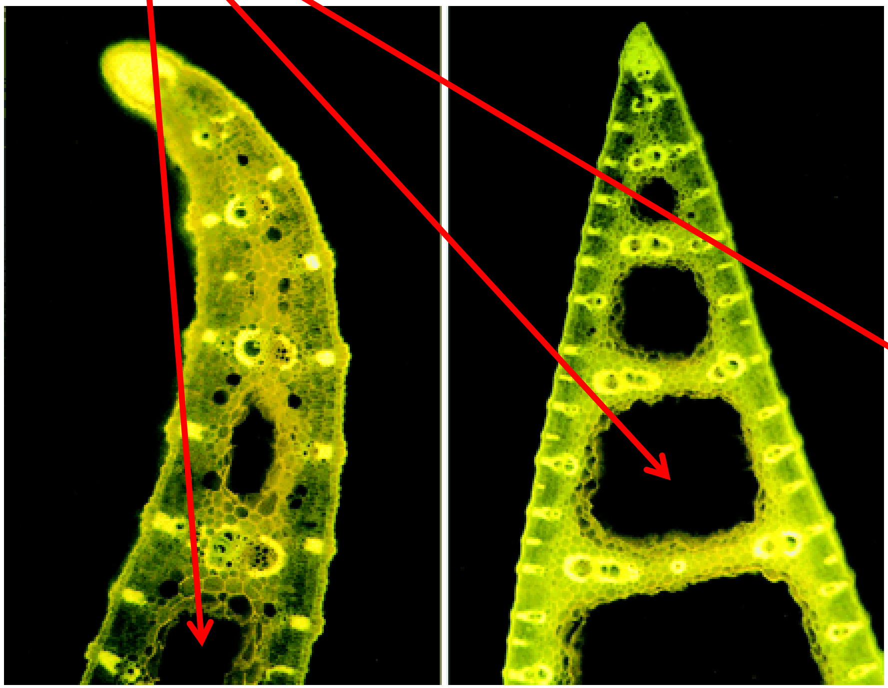
- Transporting oxygen from the air or water to the rhizomes and roots is the solution.



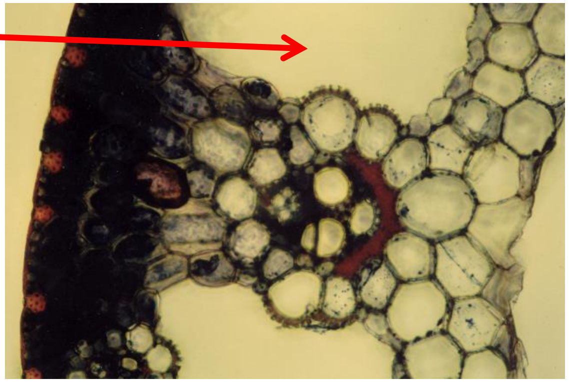
<u>Flooding tolerance</u>:

The adaptations that allow wetland plants to grow in waterlogged, anaerobic soils and standing water, where most plants cannot grow.

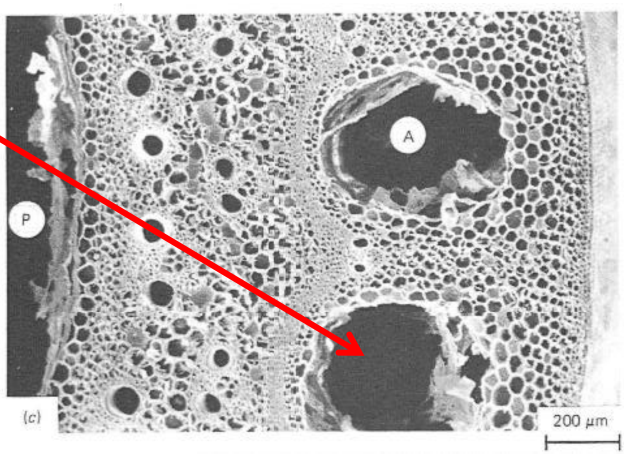
Aerenchyma: Large airspaces for transporting oxygen from atmosphere to roots



Microscope cross-section of cattail leaf



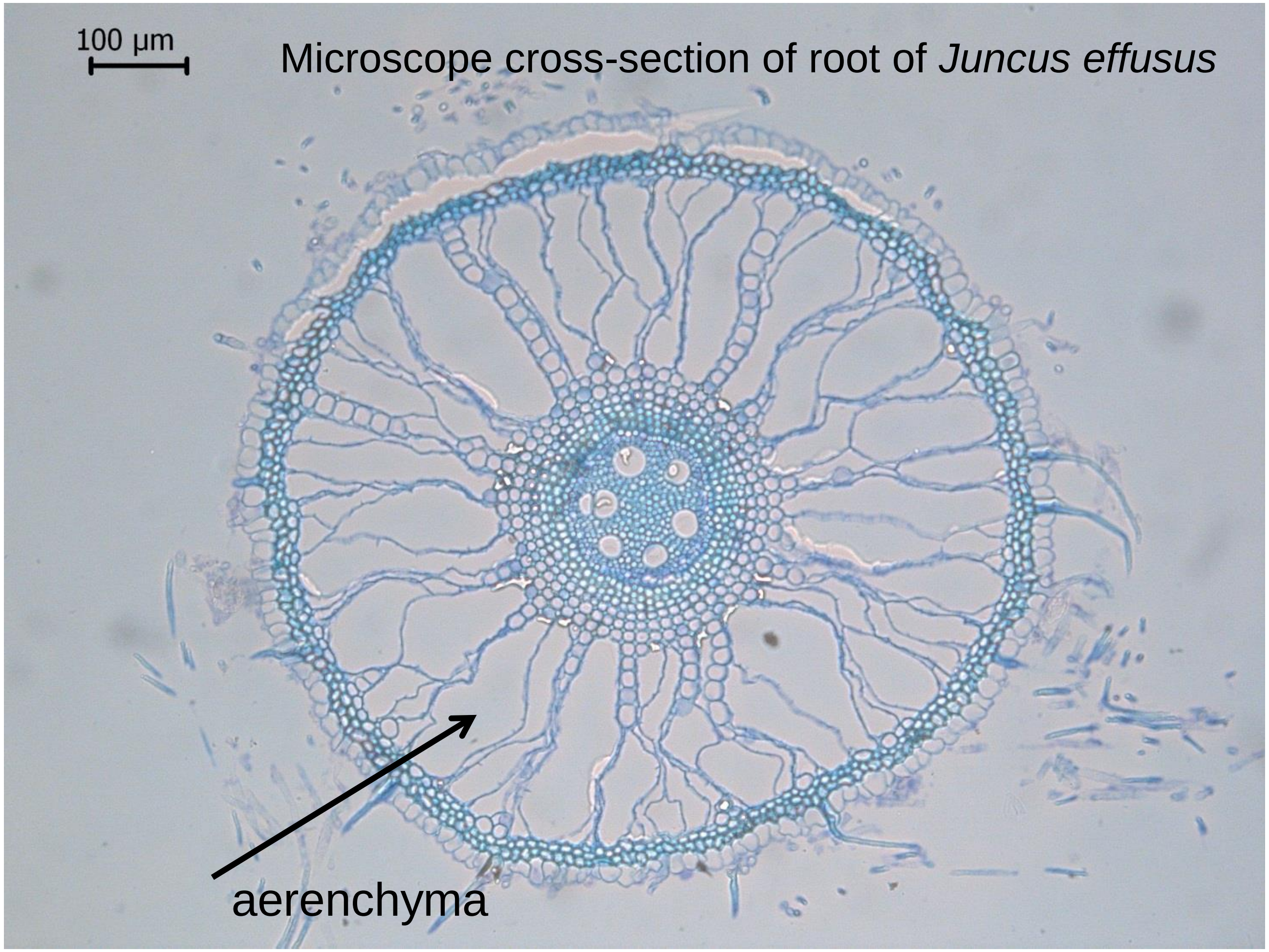
Eleocharis (spike-rush)



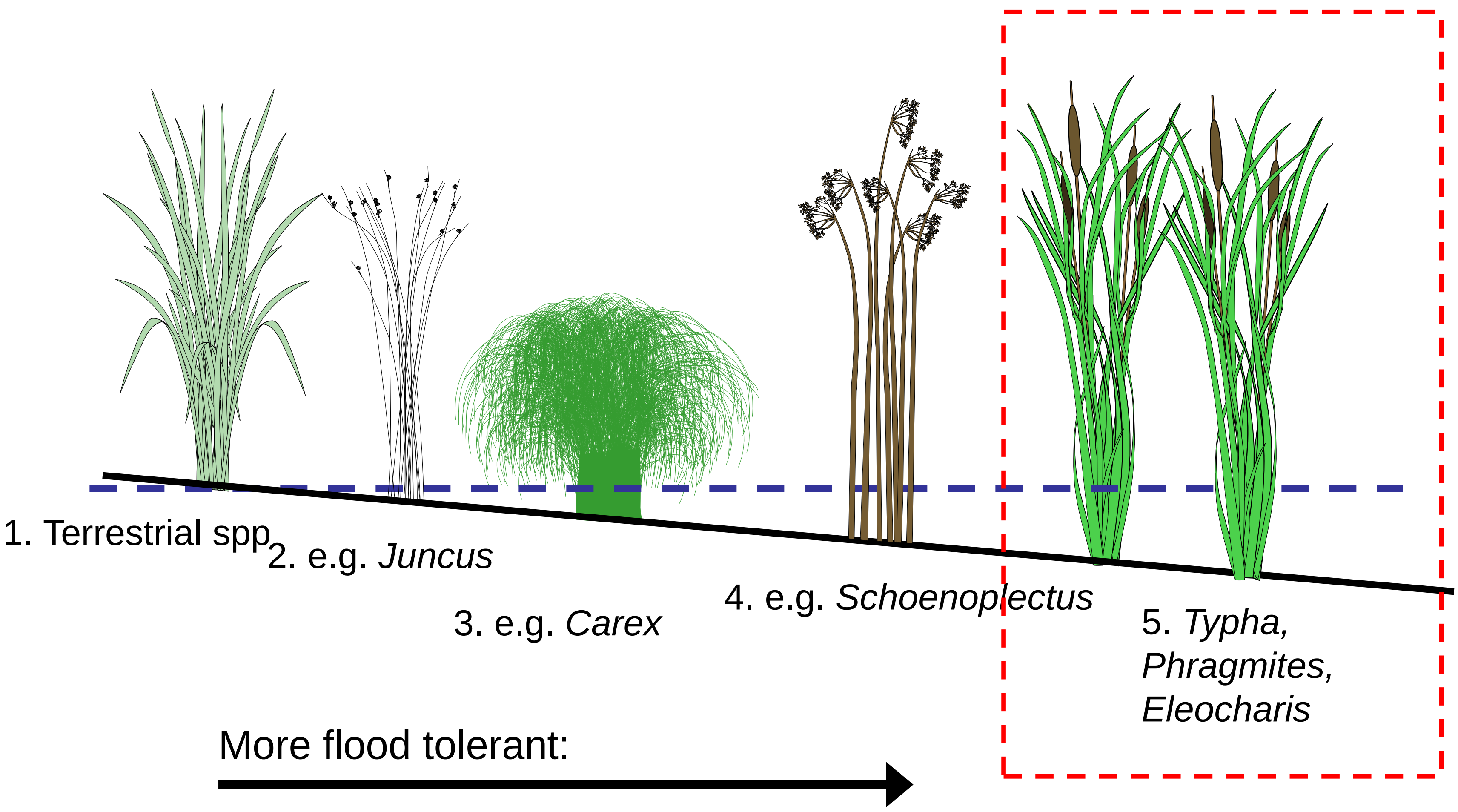
Phragmites

Flooding tolerance:

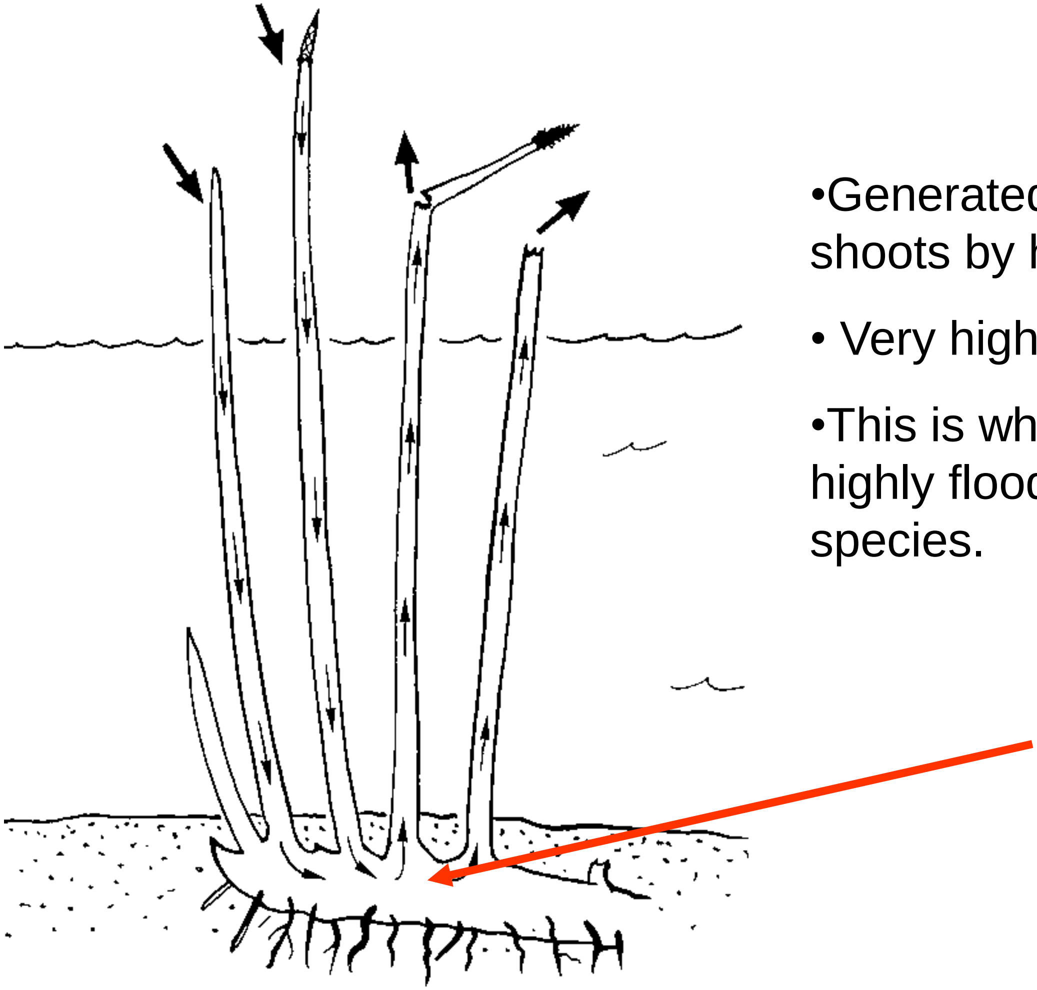
The adaptations that allow wetland plants to grow in waterlogged, anaerobic soils and standing water, where most plants cannot grow.



- <u>Flooding tolerance</u>:
- Differences in flooding tolerance structure species zonation along depth gradients, and competition and survival in response to flooding.



- **Plants that can grow in deep water:**
- Have a pressurised gas flow that blows air through the plant, ventilating it with oxygen to support aerobic metabolism

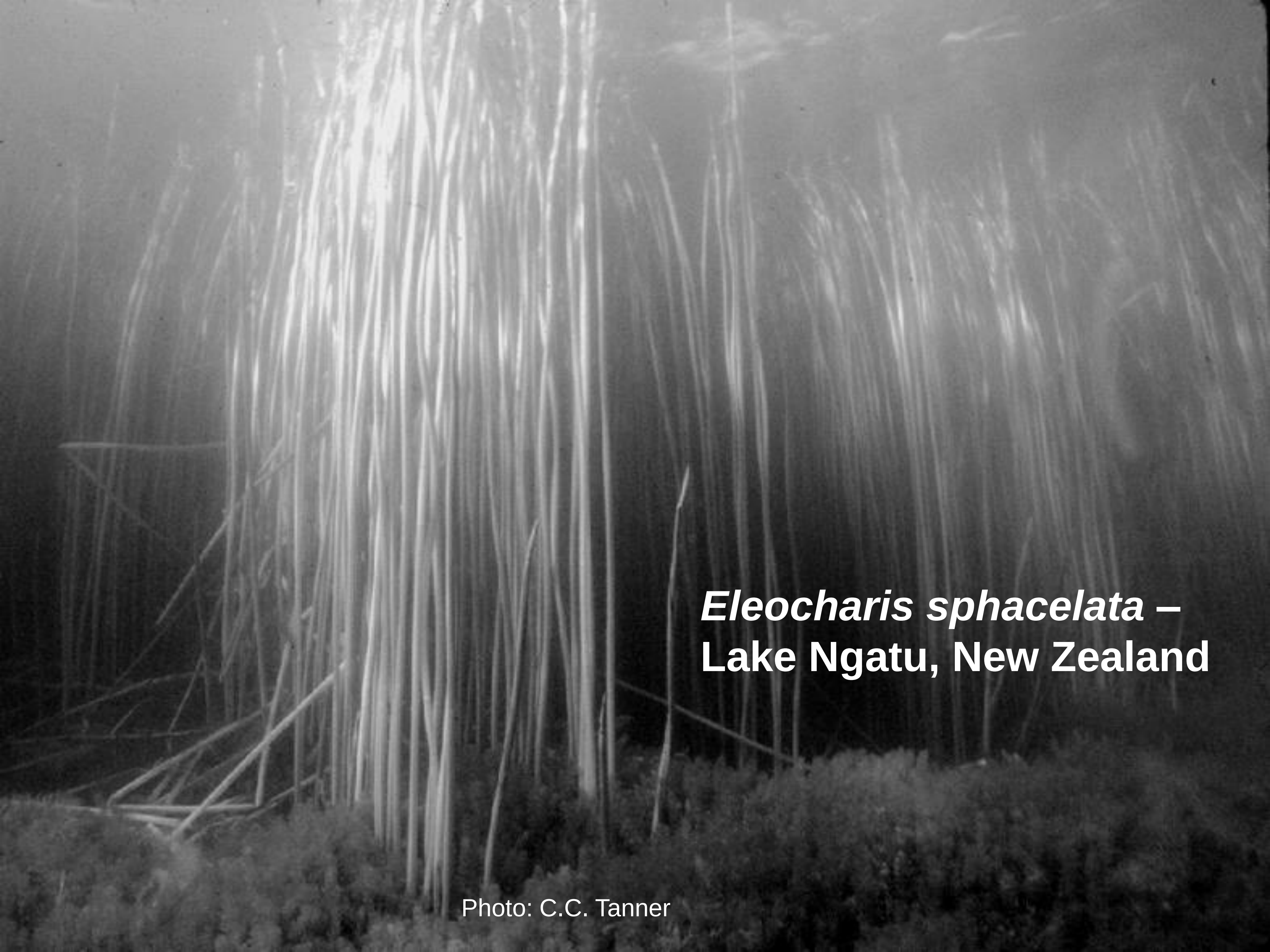


•Generated by pressurisation of live shoots by humidity gradients.

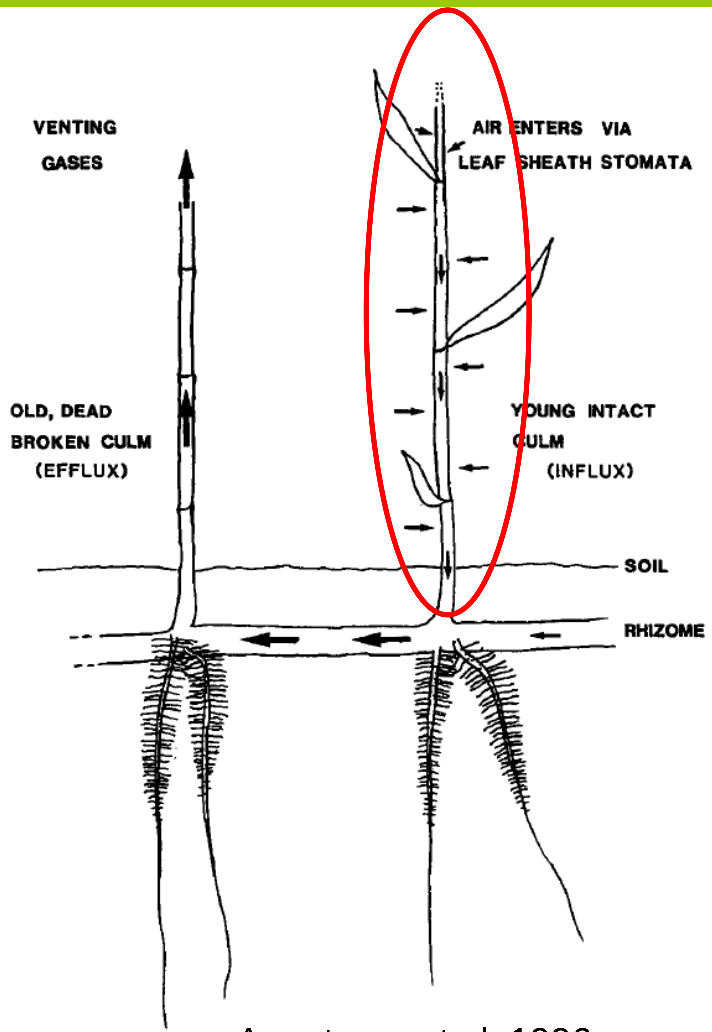
• Very high internal oxygen fluxes**.**

•This is what separates out the very highly flood-tolerant and deep-growing species.

Maintains higher internal oxygen concentrations at root base – *indirectly* benefits roots.


Eleocharis sphacelata –
Lake Ngatu, New Zealand
Photo: C.C. Tanner

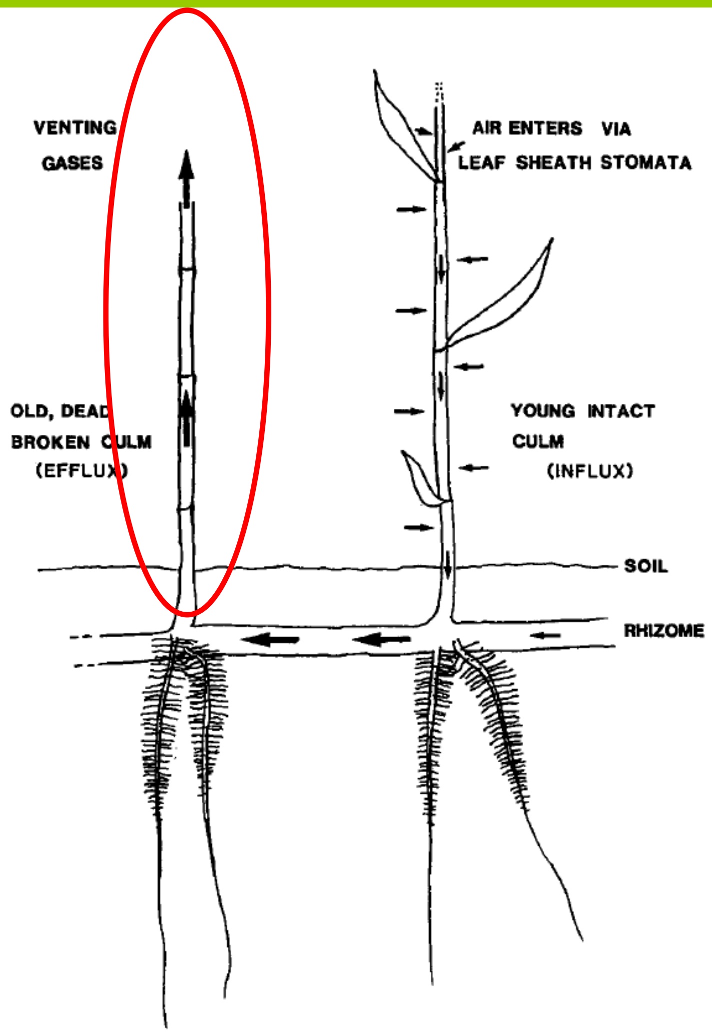
Phragmites australis: Has pressurised convective gas flow in shoot & rhizome aerenchyma



Armstrong et al. 1996

- Pressures are generated diurnally in live green shoots – “influx shoots”
- Pressuríse due to humidity gradients driving air molecules into the **leaf sheath** airspaces via stomata.
- Pressurised gas in the leaf sheath enters the hollow stems at the nodes.

Phragmites australis: Has a humidity-induced convective gas flow in shoot aerenchyma



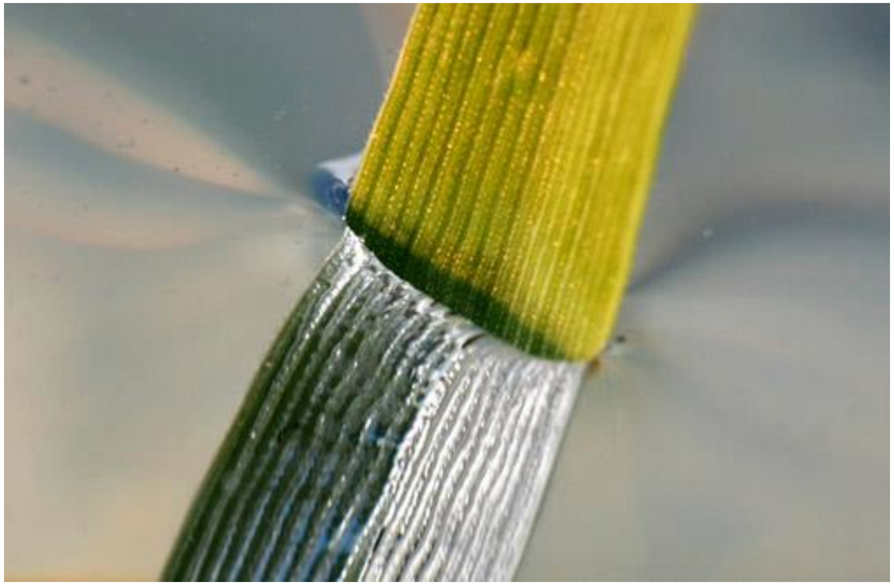
- Gas flows through rhizomes and ventilated to the atmosphere in old dead culms (“efflux culms”).
- Very high internal oxygen fluxes c.f. simple diffusion**.**
- Beneficial for growth in deep water and maintaining high rhizome biomass.

(1) Pressures → (2) Flows → (3) Aeration (pO_2)

Measuring gas flow capacity in experiments

Phragmites: Also has leaf gas films that enhance underwater gas exchange

- Hydrophobic surfaces on leaves trap gas films underwater.
- Improve underwater gas exchange between leaf and water: photosynthesis and respiration.
- **Especially beneficial for plants that live with fluctuating water levels.**



Photos: O. Pedersen

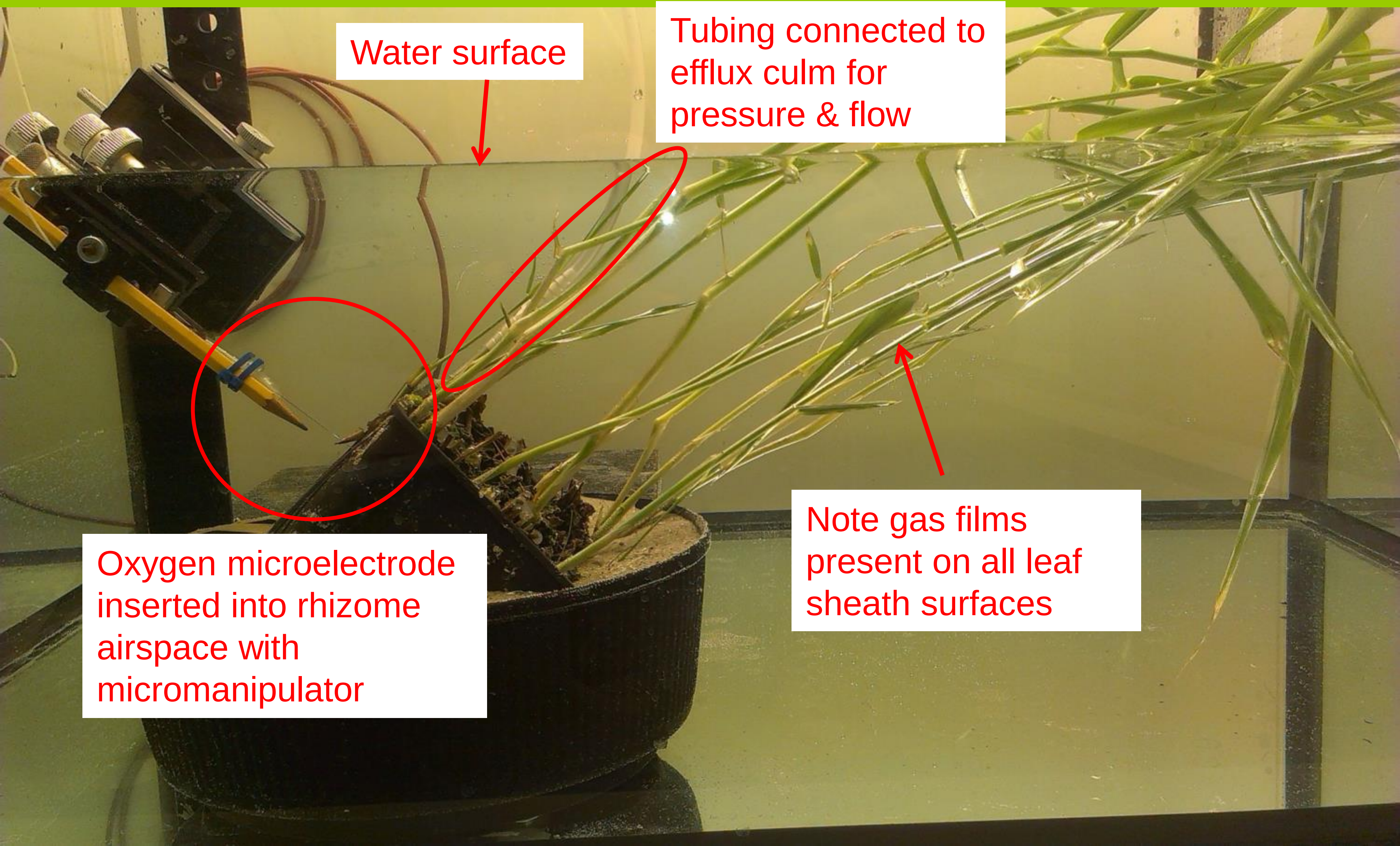
<u>Hypothesis:</u> The presence of gas films on the leaf sheaths (=the pressurising surface) assists in maintaining convection and aeration in flooded *Phragmites*

Experimental design

- Treatments:
  - (1) no flooding (control);
  - (2) partial flooding;
  - (3) complete submergence.

- \- and **with intact gas films** or **with gas films removed**

Measurements: The internal pressure, gas flow generated, and rhizome pO_2 sustained under these treatments.



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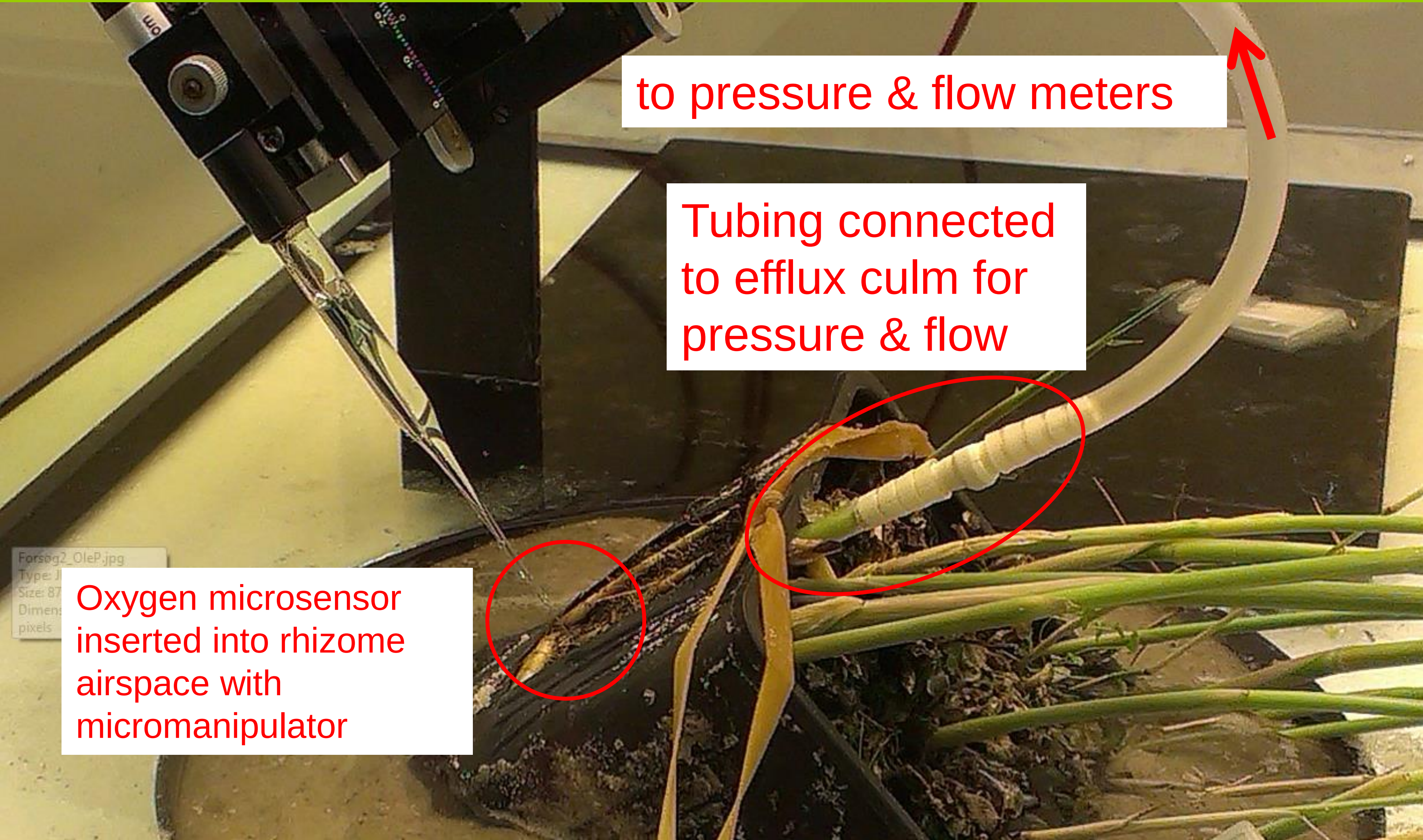
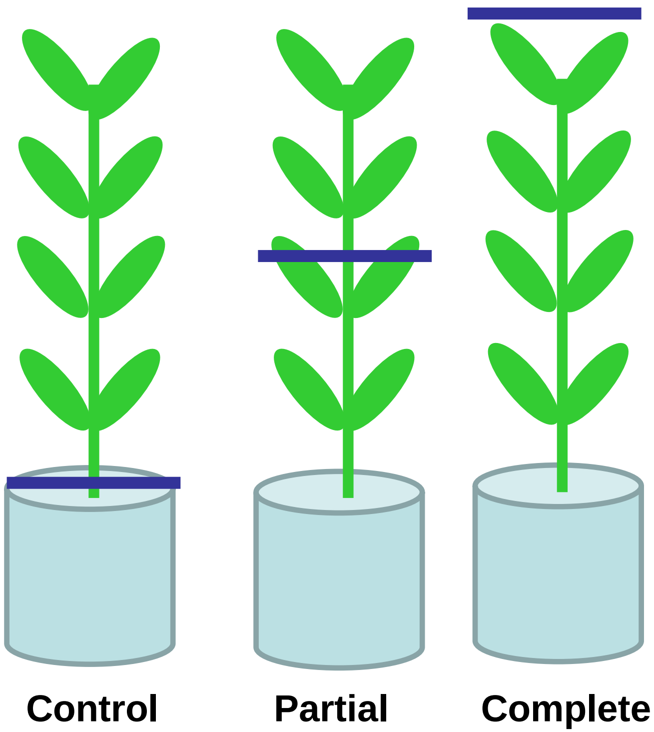
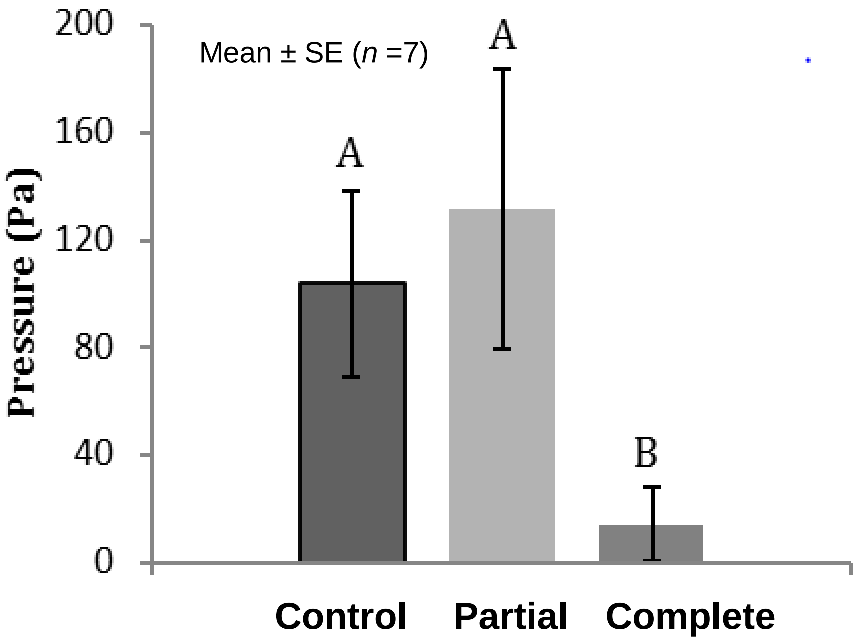


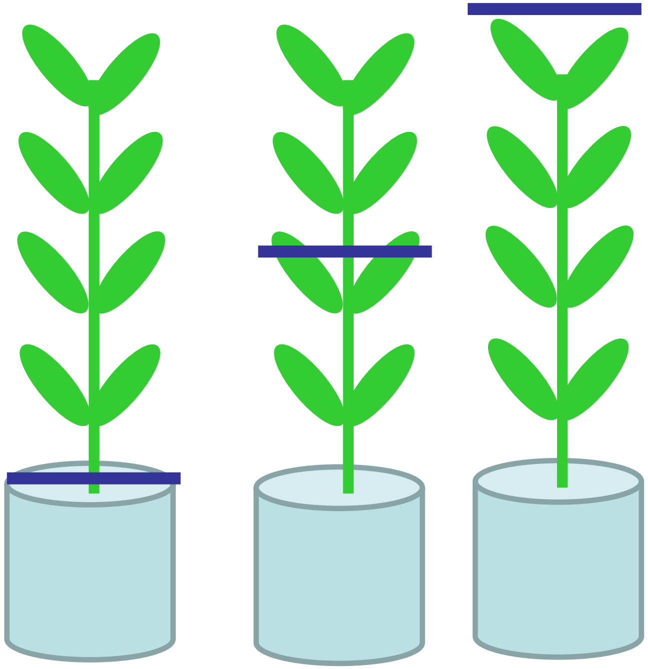
Flooding: What is the effect of partial and complete flooding on internal pressurisation? (with gas films)

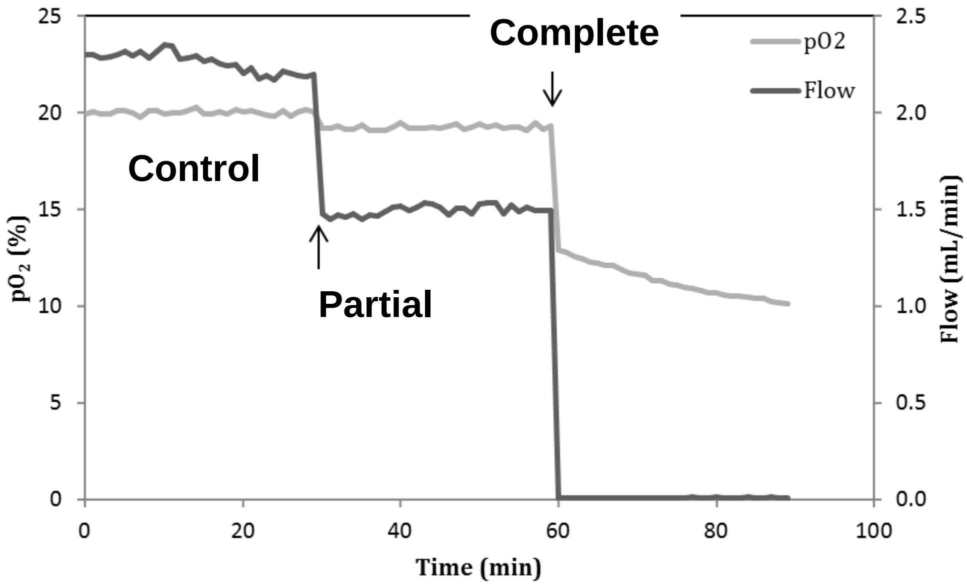




- Partially submerged plants pressurize just as well as control plants.
- Complete submergence lowers the humidity gradient (gas film is humid) – much lower pressurisation capacity.

Flooding: What is the effect of partial and complete flooding on gas flows and rhizome aeration? (with gas films)

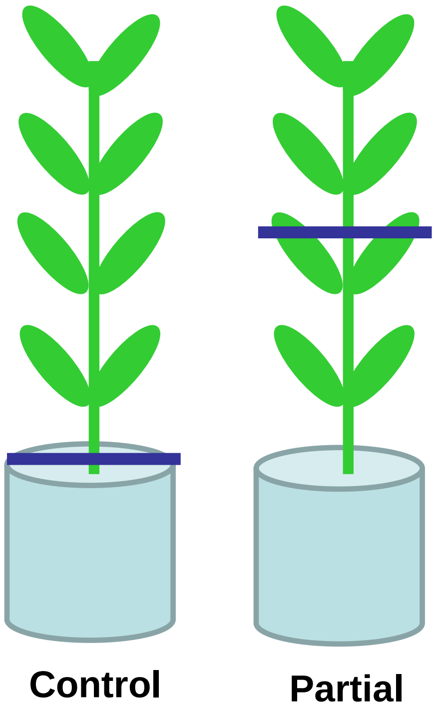


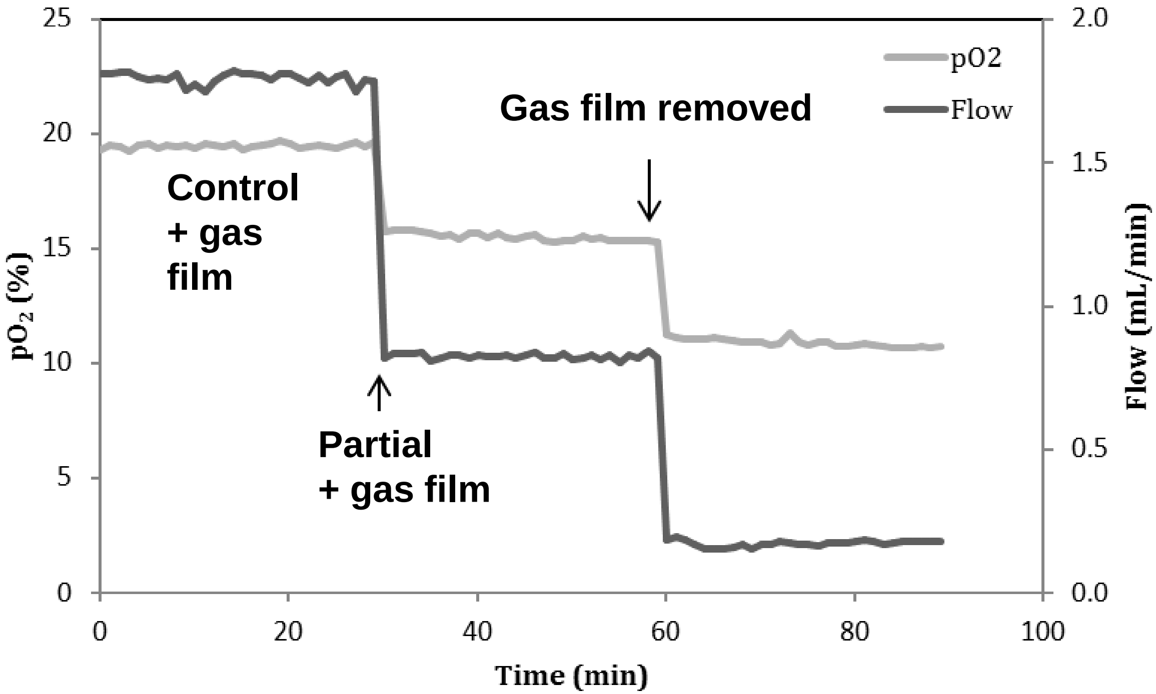


Time course:

- Flow decreasing under partial flooding, pO_2 decreases slightly.
- Complete flooding even with gas films completely inhibits gas flow, and rhizome pO_2 steadily declines.

Partial flooding: Can partially flooded plants sustain flows and aeration with and without gas films?





Time course :

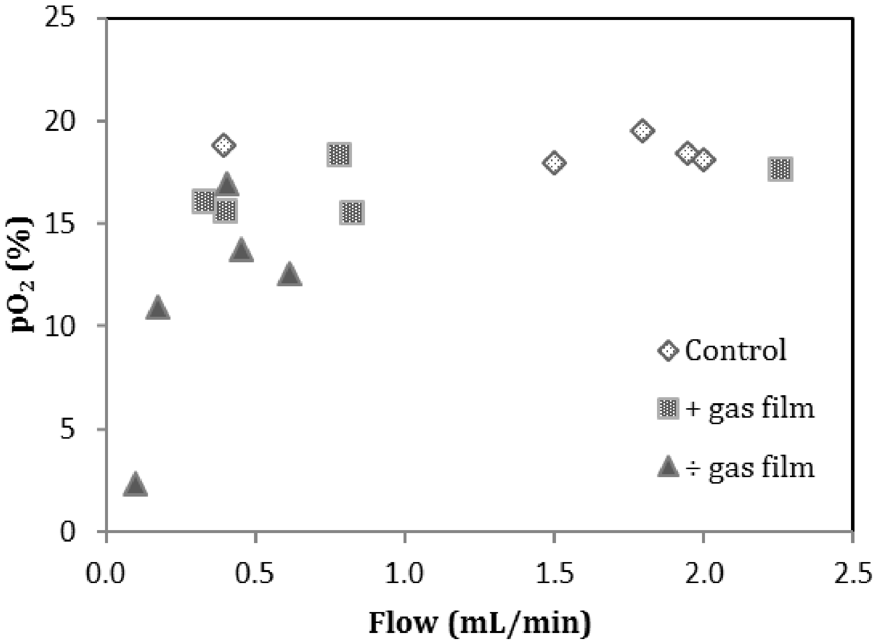
- Without the gas film, but flow decreases much more (less pressurising surface area).
- Plant is unable to sustain as much flow, so rhizome pO_2 decreases.

Flooding and gas film effects on rhizome pO_2

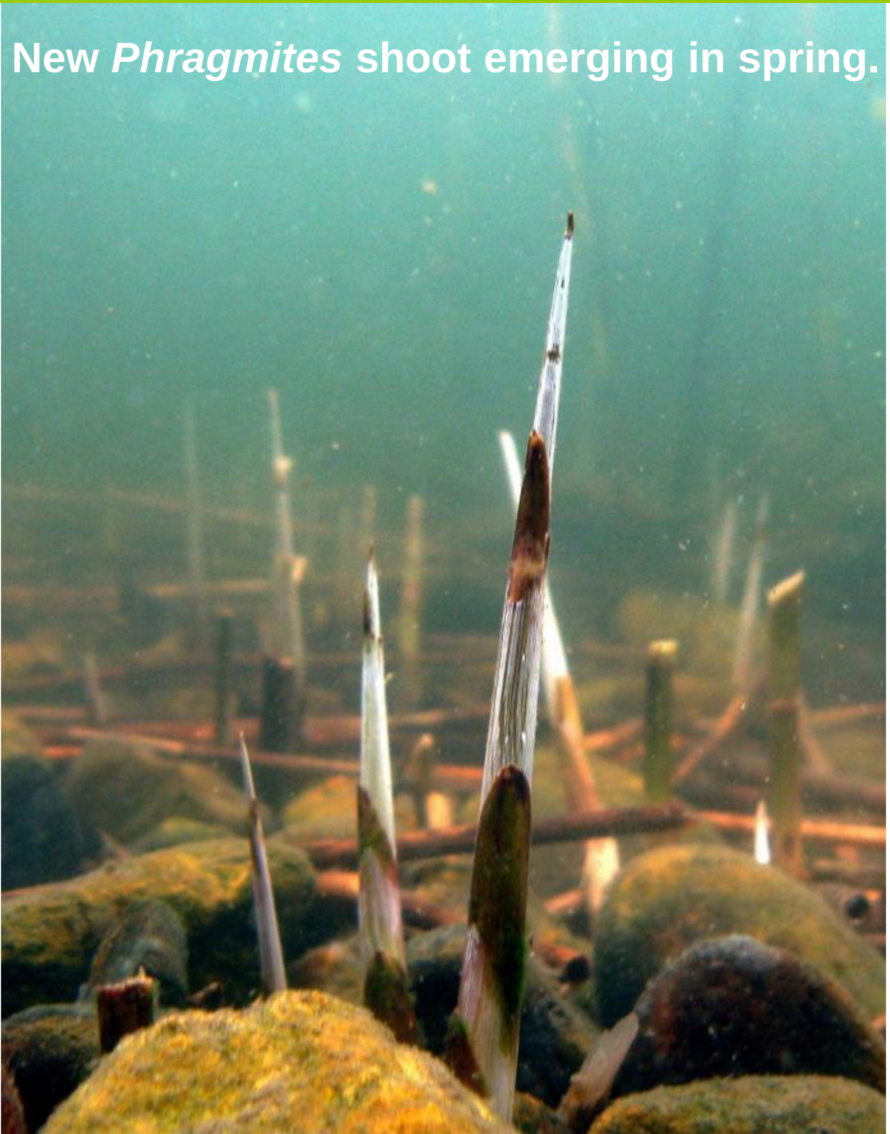
<u>Gas flow rate vs O_2:</u>

- The relationship between flow rate and rhizome pO_2 is hyperbolic.

- **Gas films** become especially important for sustaining aeration as the transport distance increases (deeper water, longer rhizome).



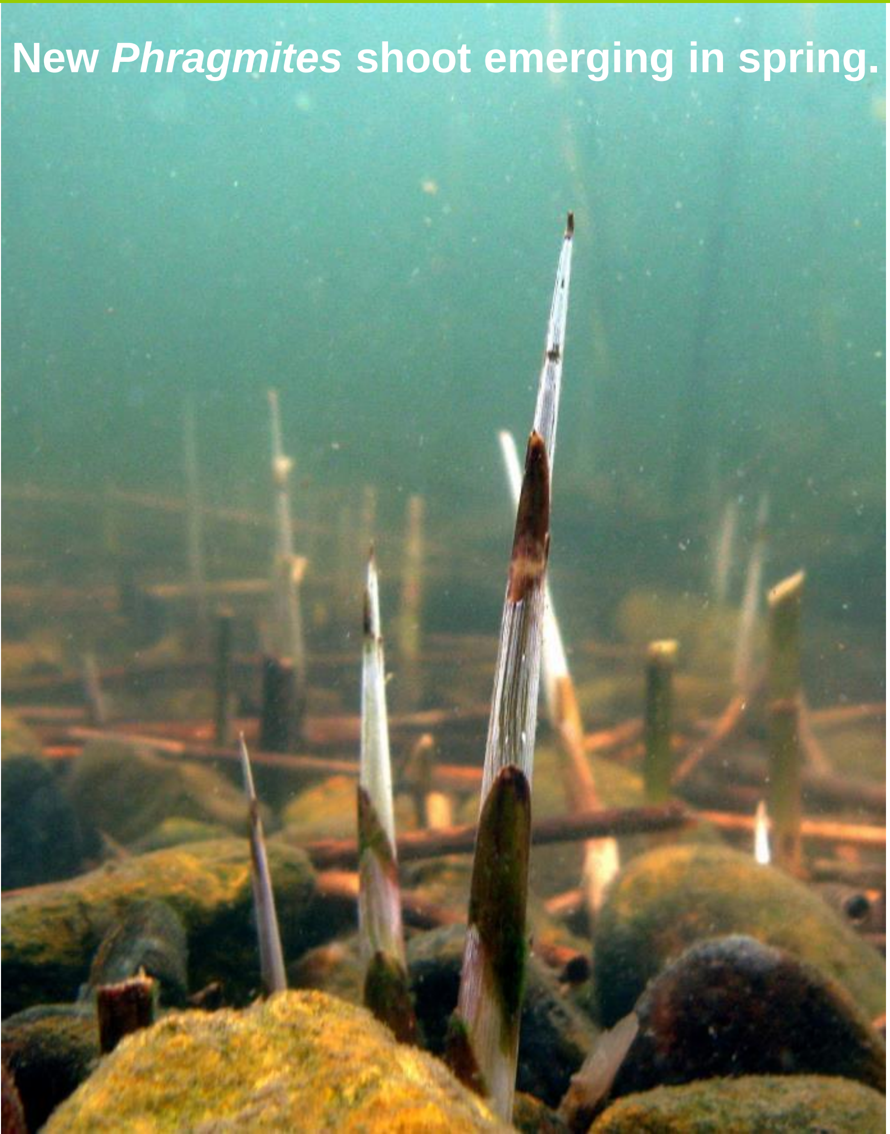
Conclusions: How important are gas films for sustaining convective flows and aeration during flooding?



- Gas films are probably <u>essential</u> for maintaining gas flow and survival in partially flooded plants.
- The larger the plant, the deeper the water, the more sudden or rapid the water level fluctuation, the more important this is.
- Even with gas films, fully submerged *Phragmites* cannot generate convective gas flow.

Photo: O. Pedersen

What does this imply for the future of wetland vegetation and *Phragmites* in particular?



- Shoreline vegetation is certainly at great risk of increased stress due to more frequent and more sudden flooding events.
- Species like *Phragmites* that have gas films will probably do better in future than species without gas films.
- Killing invasive *Phragmites* will require repeated cutting underwater – not enough to just cut aerial biomass.

Photo: O. Pedersen

Photo: C.C. Tanner