9th INTECOL INTERNATIONAL WETLANDS CONFERENCE
WETLANDS IN A COMPLEX WORLD
JUNE 3-8, 2012
ORLANDO FLORIDA, USA

Salinity changes biogeochemistry and ecosystem functioning;

on the roles of NaCl, SO_4^{2-}, and nutrients

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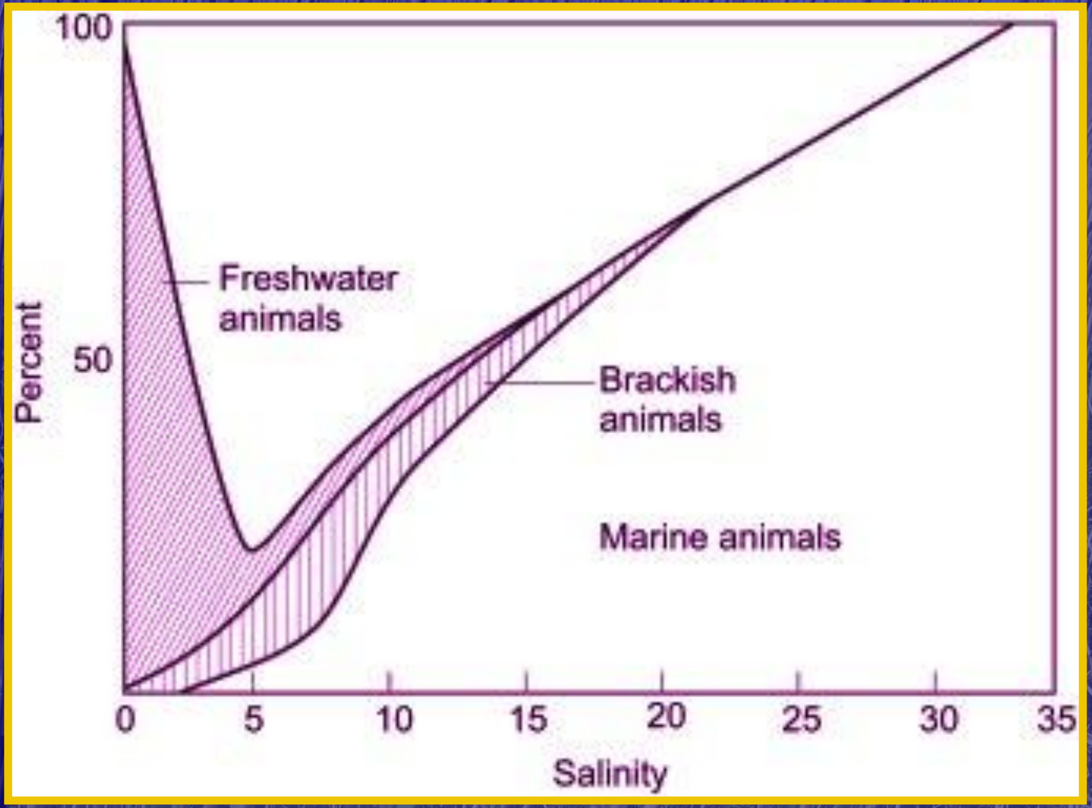
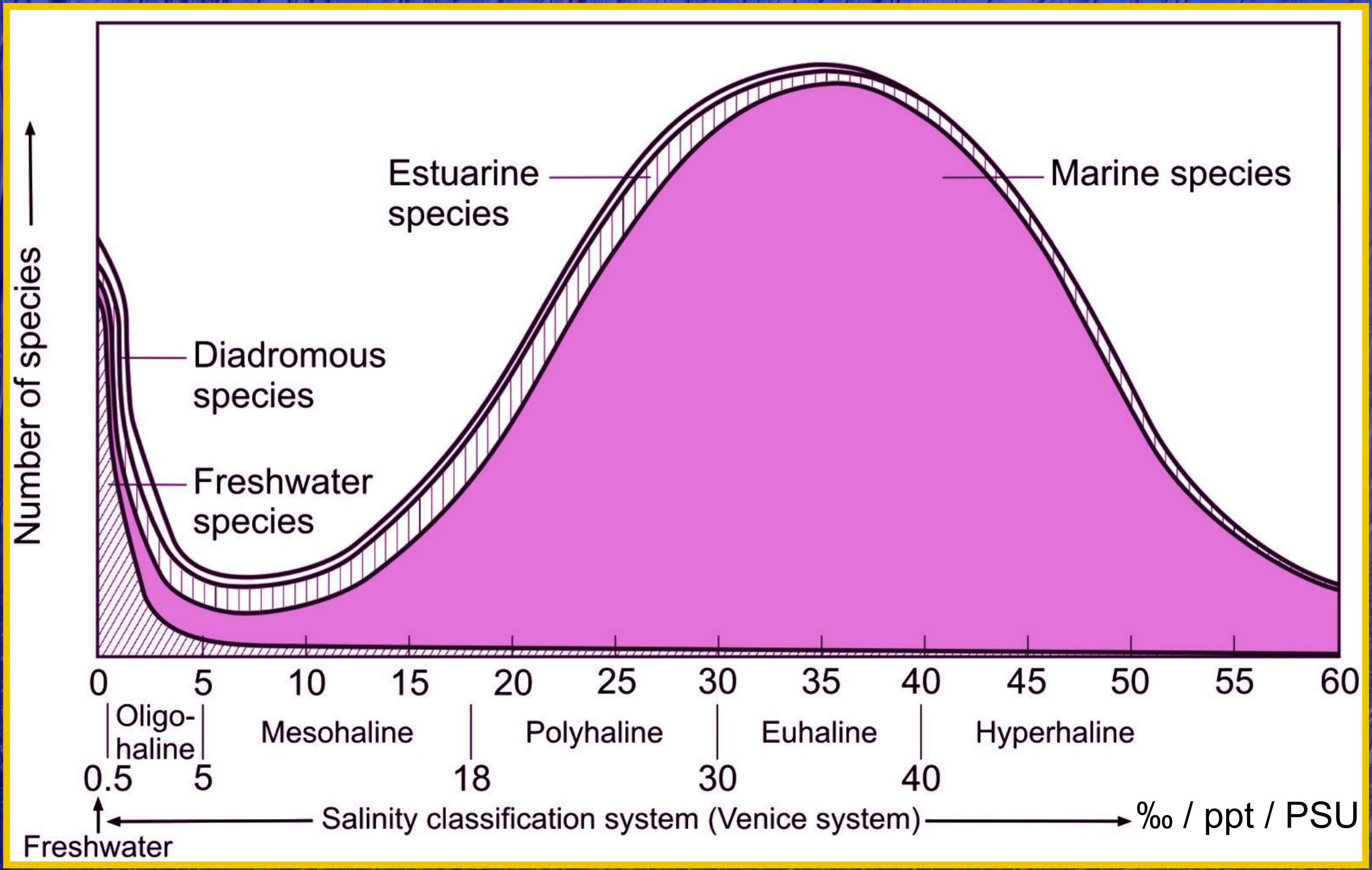
Radboud University Nijmegen
&
B-Ware Research Center

the Netherlands

- Salty challenge
- Salinization
- Biogeochemistry
- Vegetation
- Conclusion

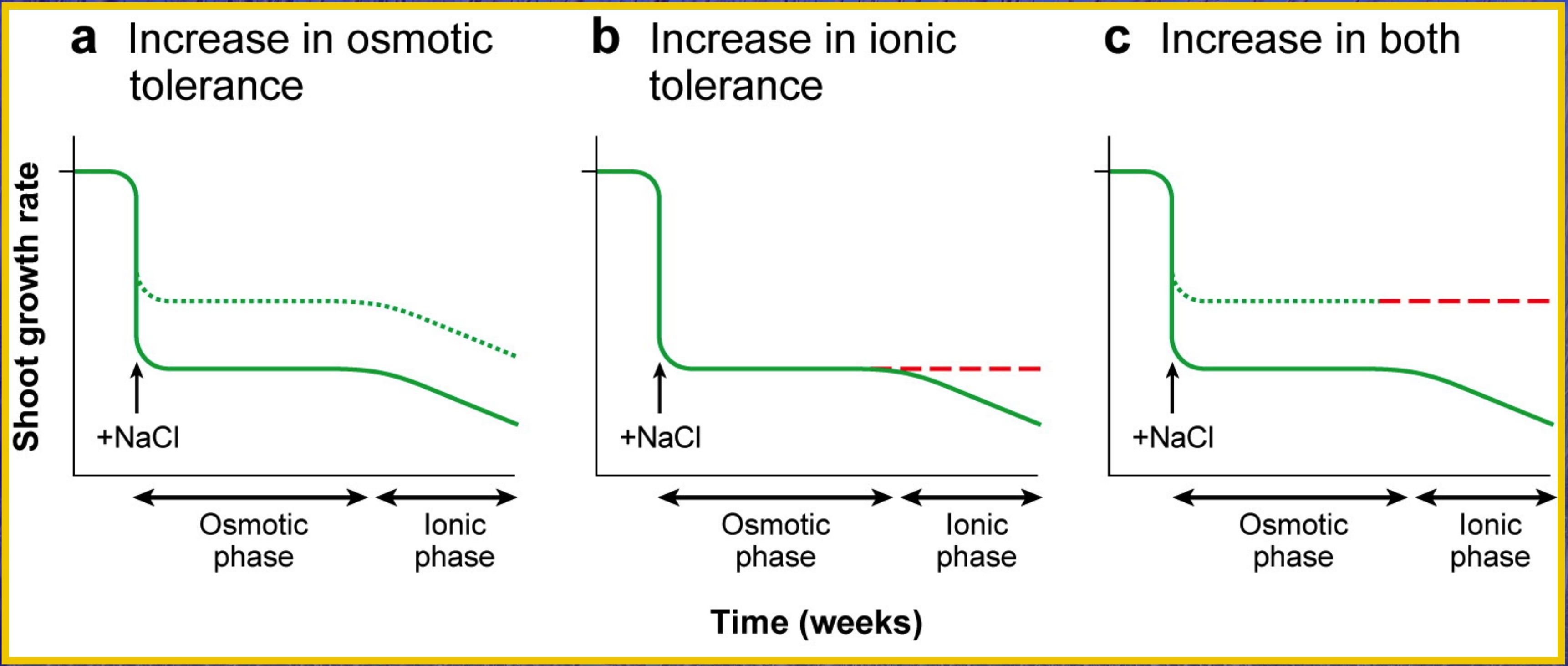


Remane 1934; Remane & Schlieper (zoobenthos) 1958



0.3	**3**	**10**	**16.5**	**22**	**g Cl L^{-1}**
8.5	**85**	**280**	**465**	**620**	**mmol L^{-1}**

Whitfield et al. Est Coast Shelf Sc 2012



Munns & Tester, Annu. Rev. Plant Biol. 2008
Parida & Das, Ecotox Environ Safety 2005

Salt exclusion

Avicennia spp.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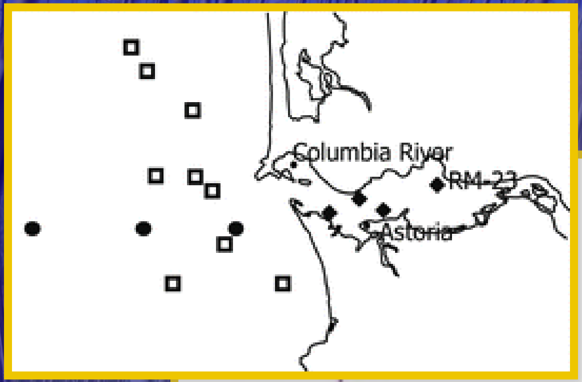
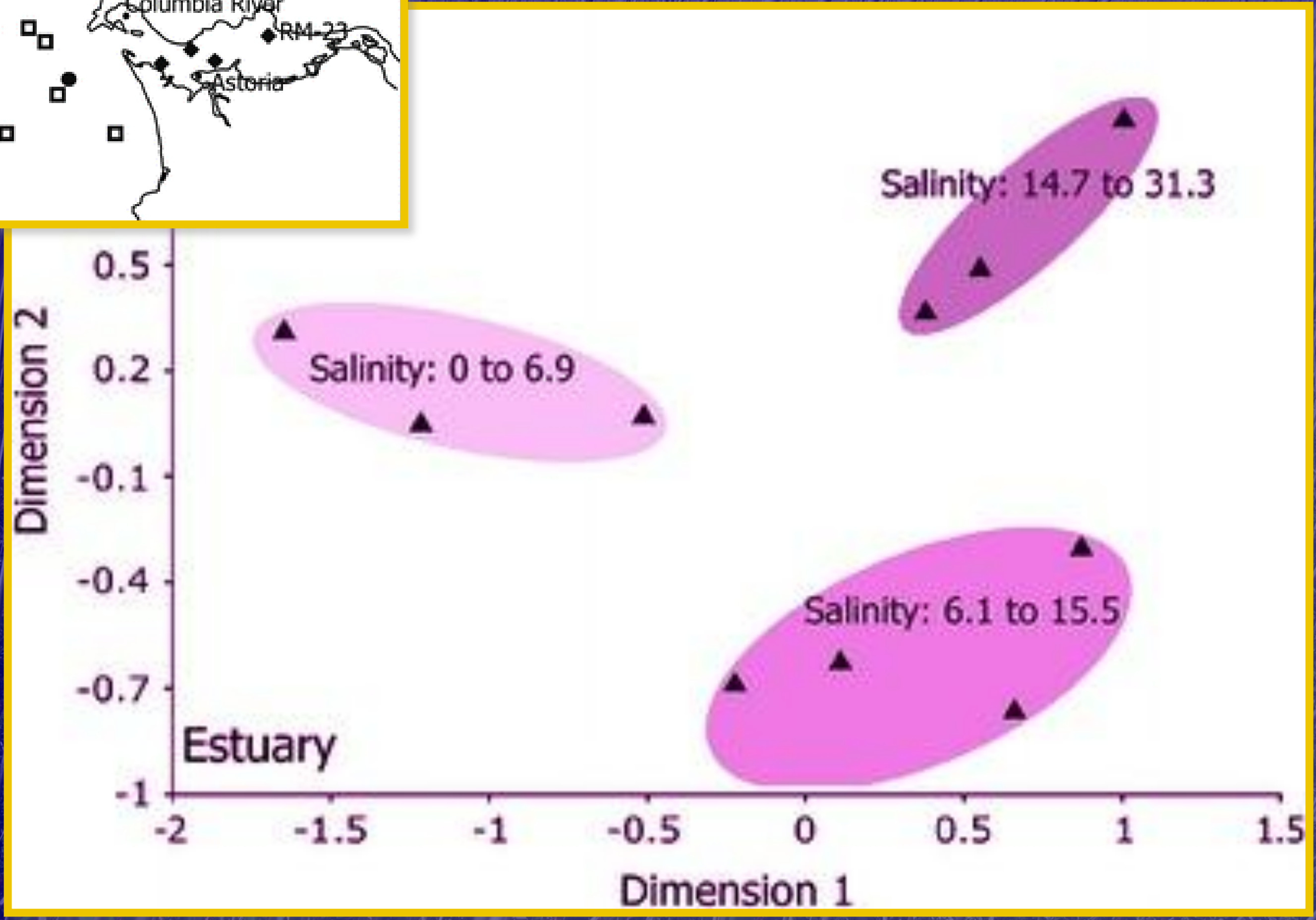
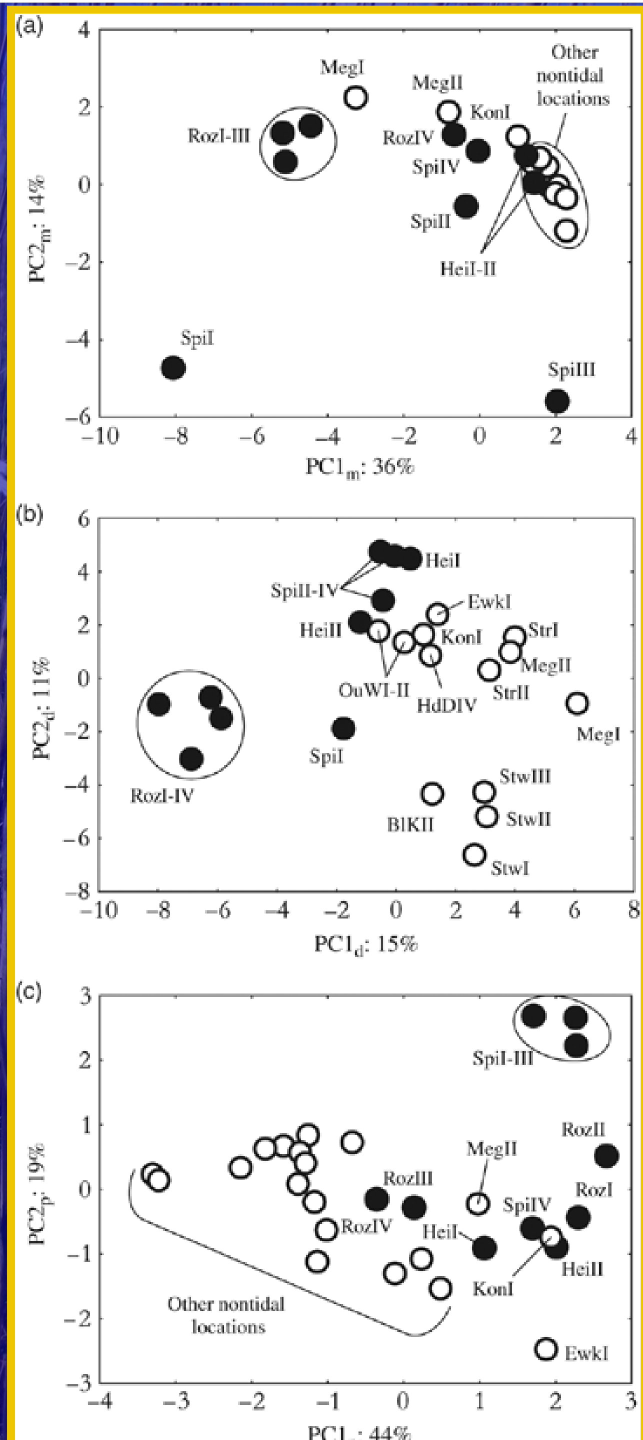




Bacterioplankton 16S rRNA; Fortunato et al. Microb Ecol 2011



microarray

DGGE

Polar lipid-derived fatty acid

SRPs; Miletto et al. FEMS Microbiol Ecol 2008

Salinization: increased salinity of surface water/soil/groundwater

Land use change

- Agriculture, urbanization, infrastructure
- Wetland and woodland destruction
- Land reclamation
- Vegetation destruction, desertification

Hydrological change

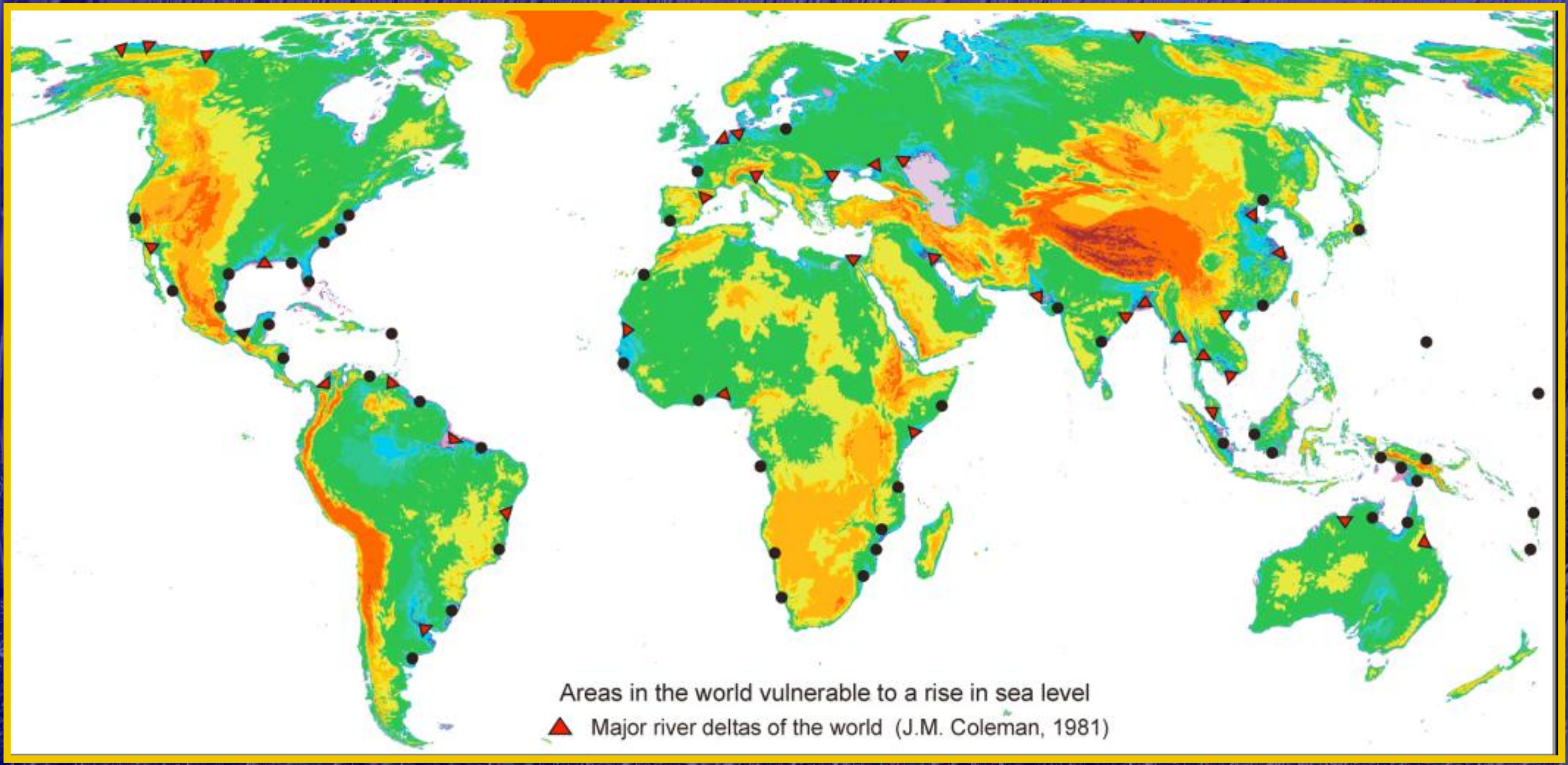
- Land drainage and lowering groundwater level
- Freshwater abstraction (groundwater, surface water) for agriculture, processing & drinking water
- Land subsidence
- Increased water run-off (low water retention)
- Irrigation channels
- Reduced freshwater flow to coast
- Coastal canals
- Subsoil freshwater storage

Erosion

- Erosion to saline layers

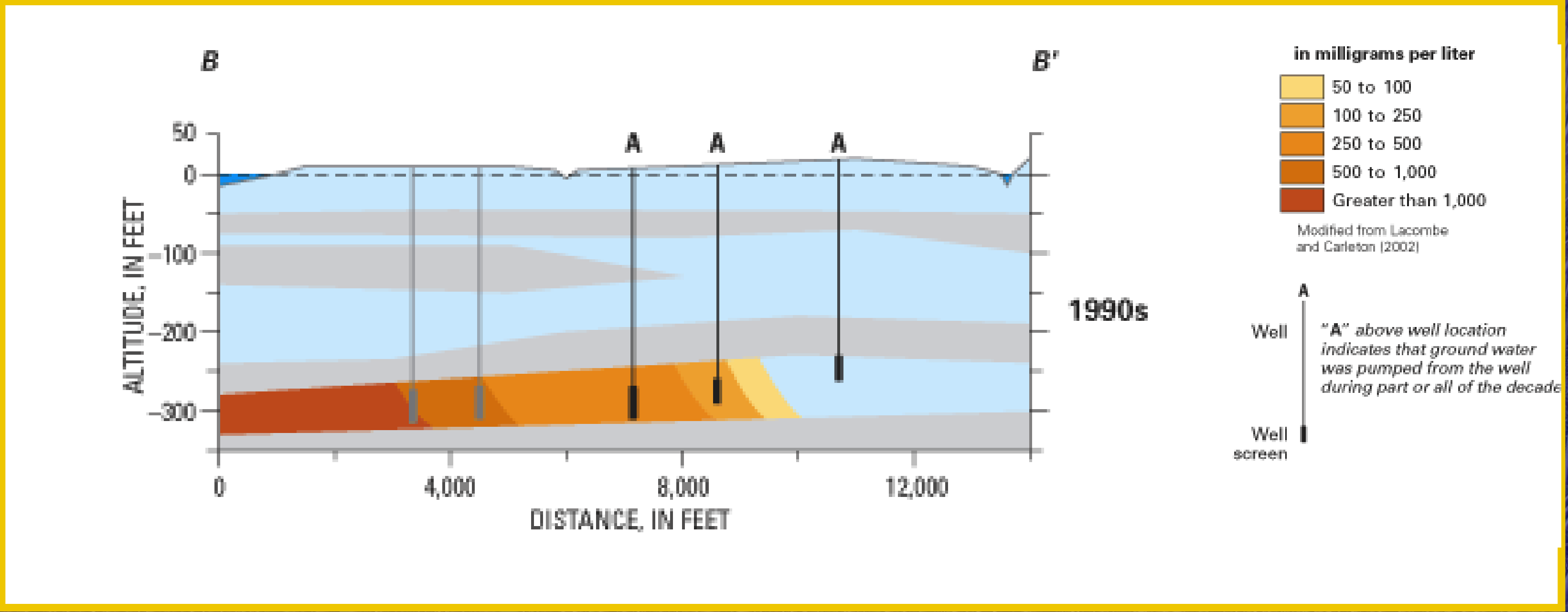
Climate change

- Reduced rainfall
- Higher T and evapotranspiration
- Sea level rise

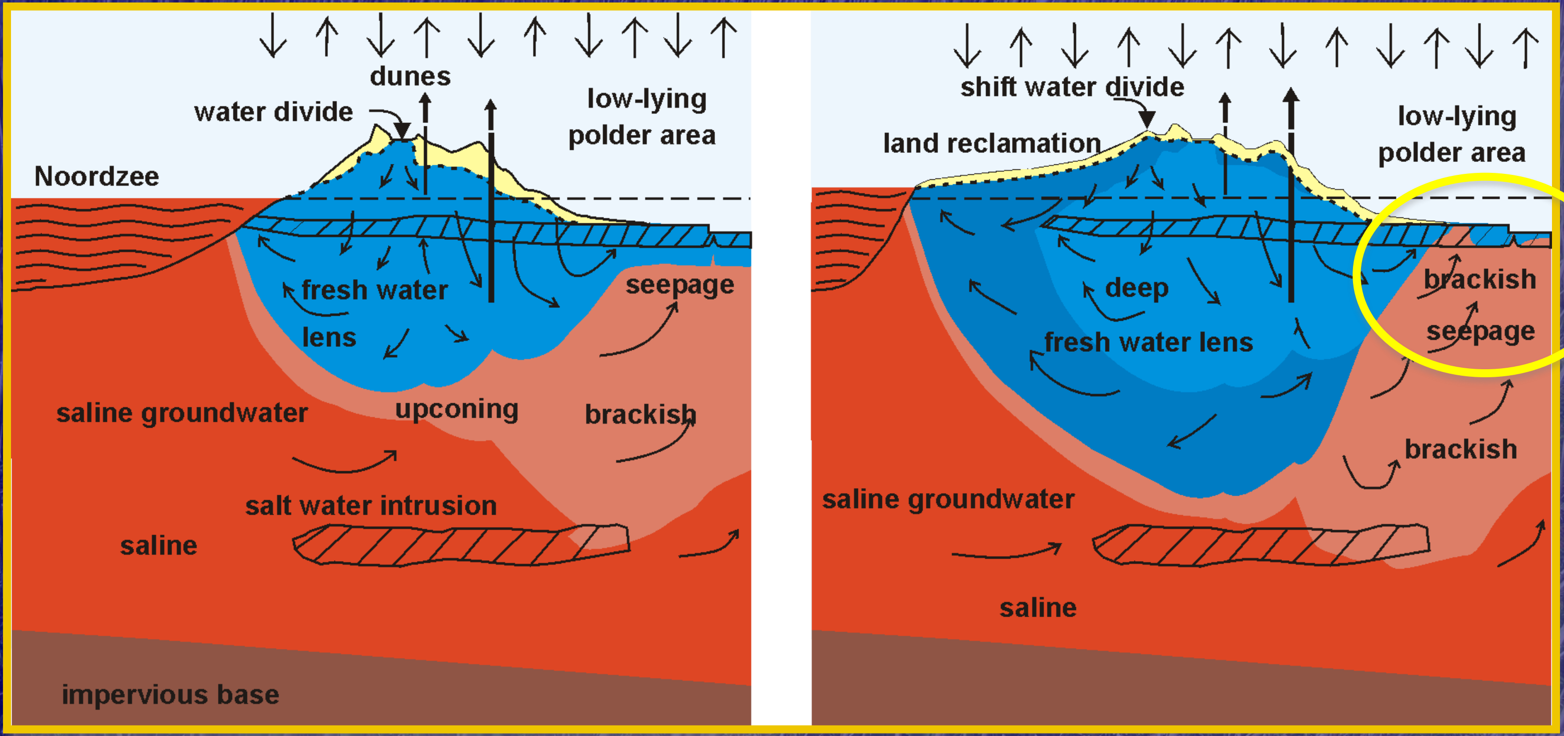


Oude Essink et al. 2010

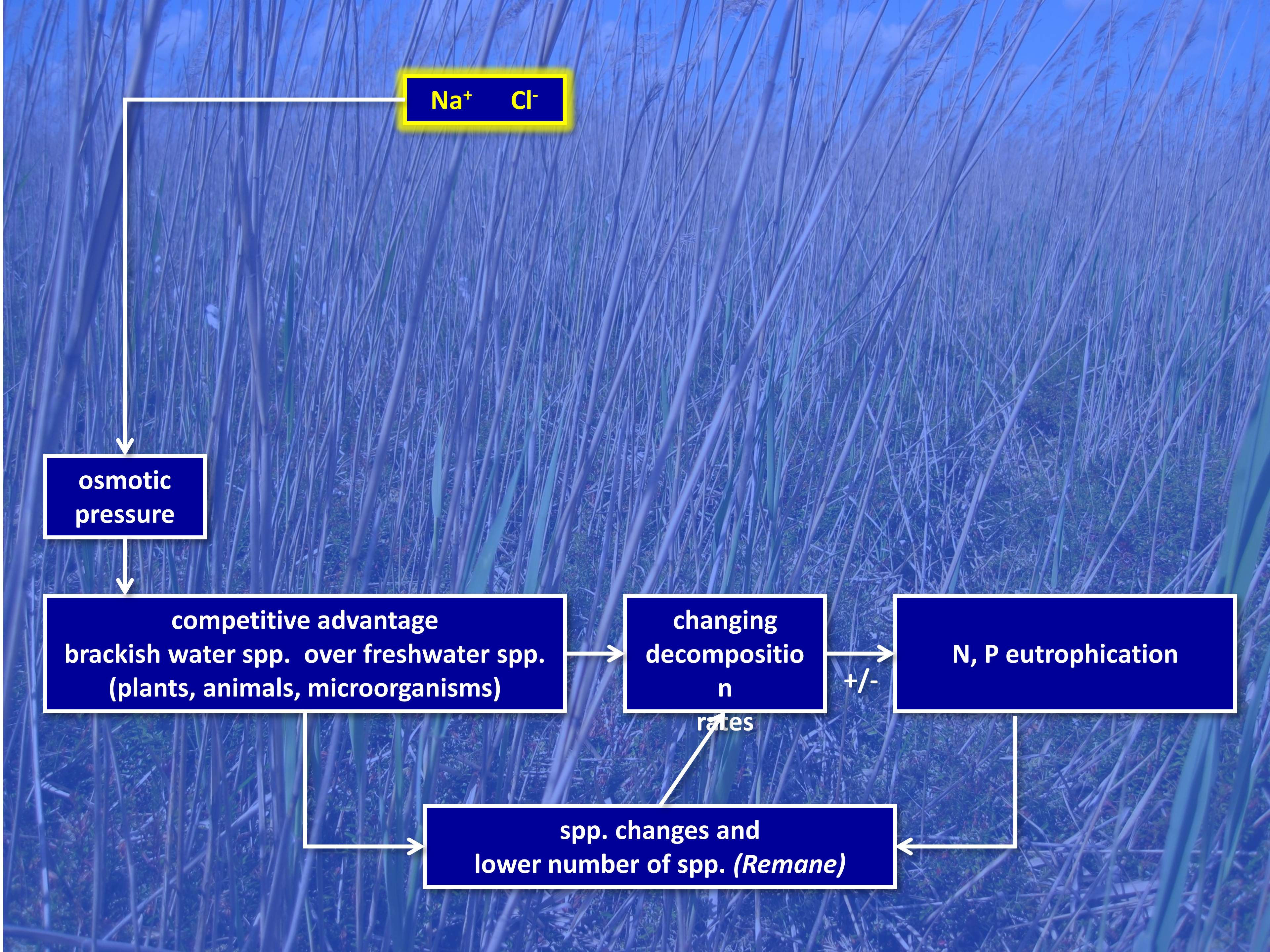
New Jersey coastal area

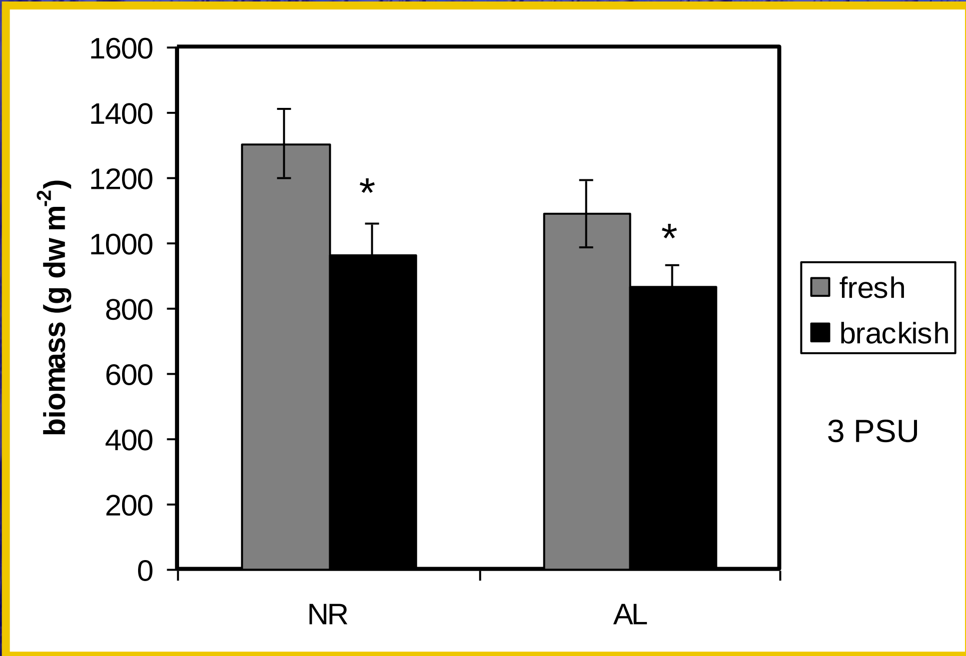


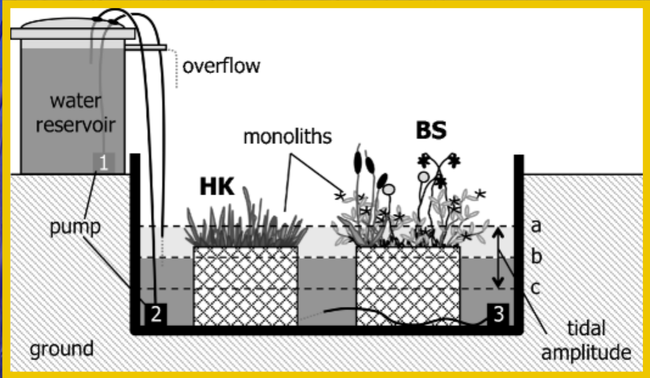
Barlow 2003



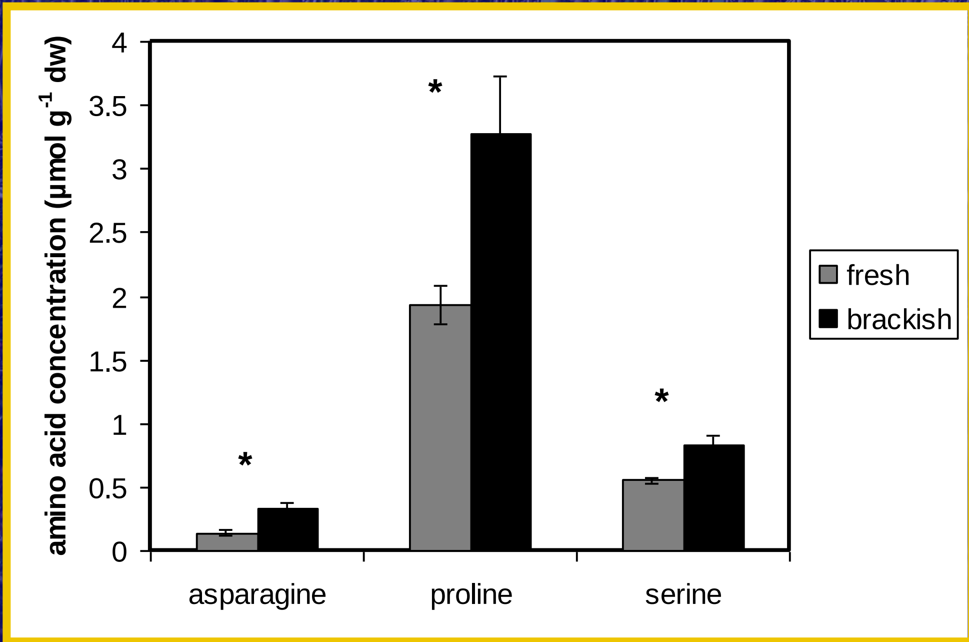
Oude Essink 2010
Stuyfzand 1993


Na^{+} Cl^{-}
osmotic pressure
competitive advantage
brackish water spp. over freshwater spp.
(plants, animals, microorganisms)
changing
decompositio
n
rates
+/-
N, P eutrophication
spp. changes and
lower number of spp. *(Remane)*

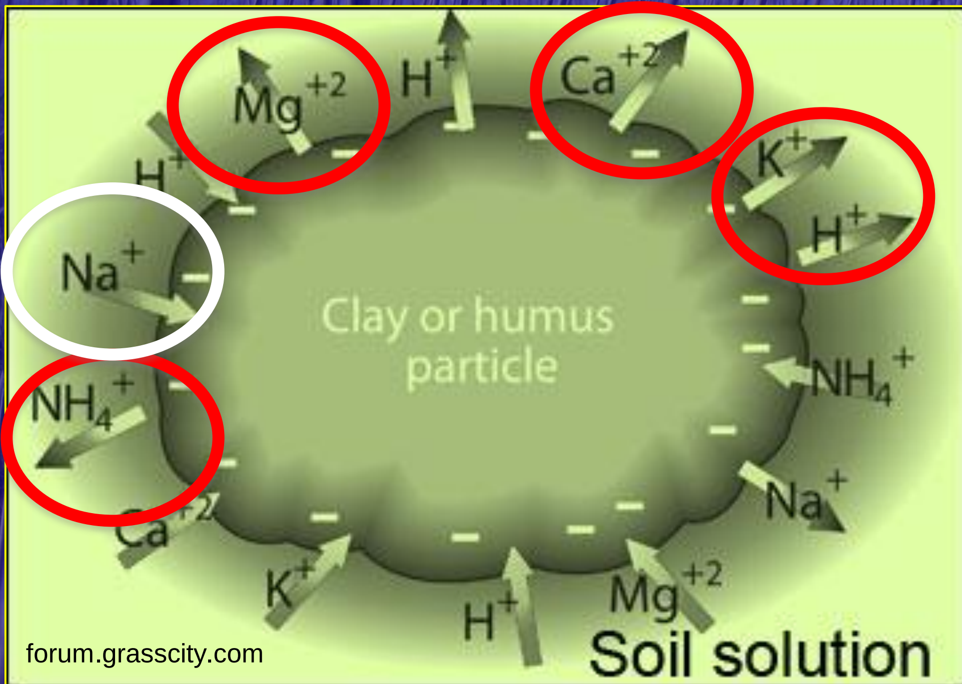


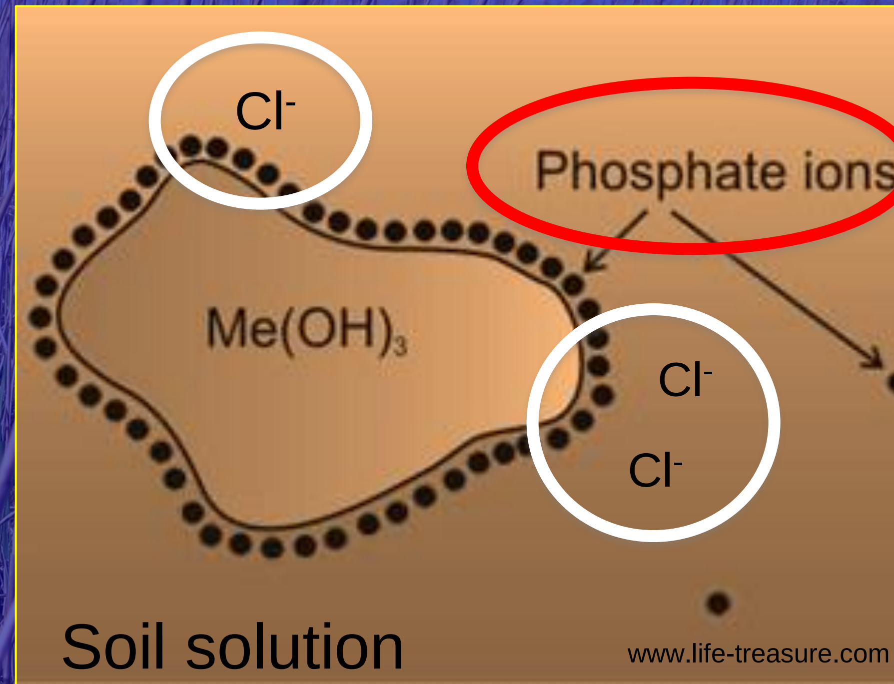


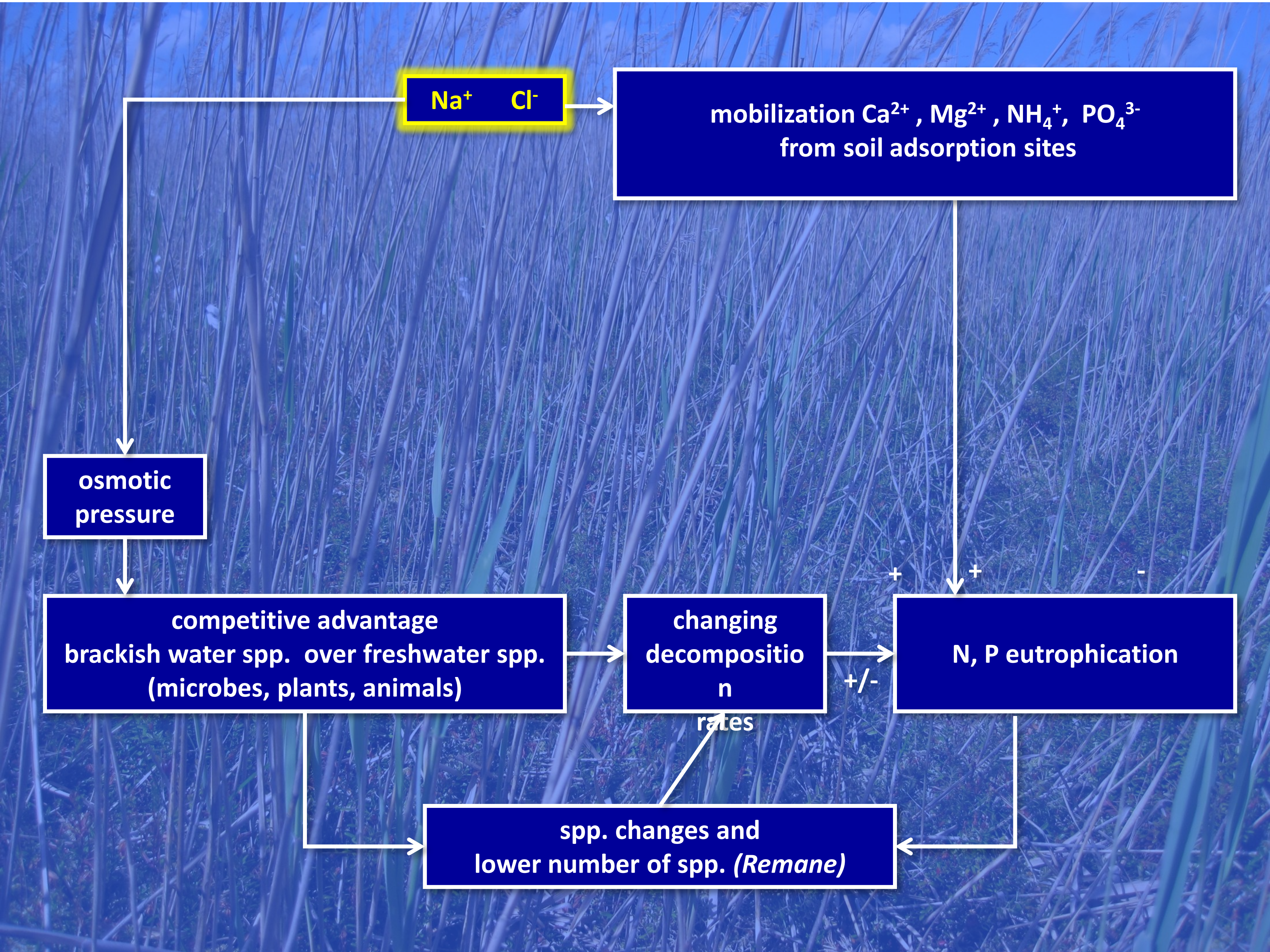
NR = nature reserve
AL = agricultural land



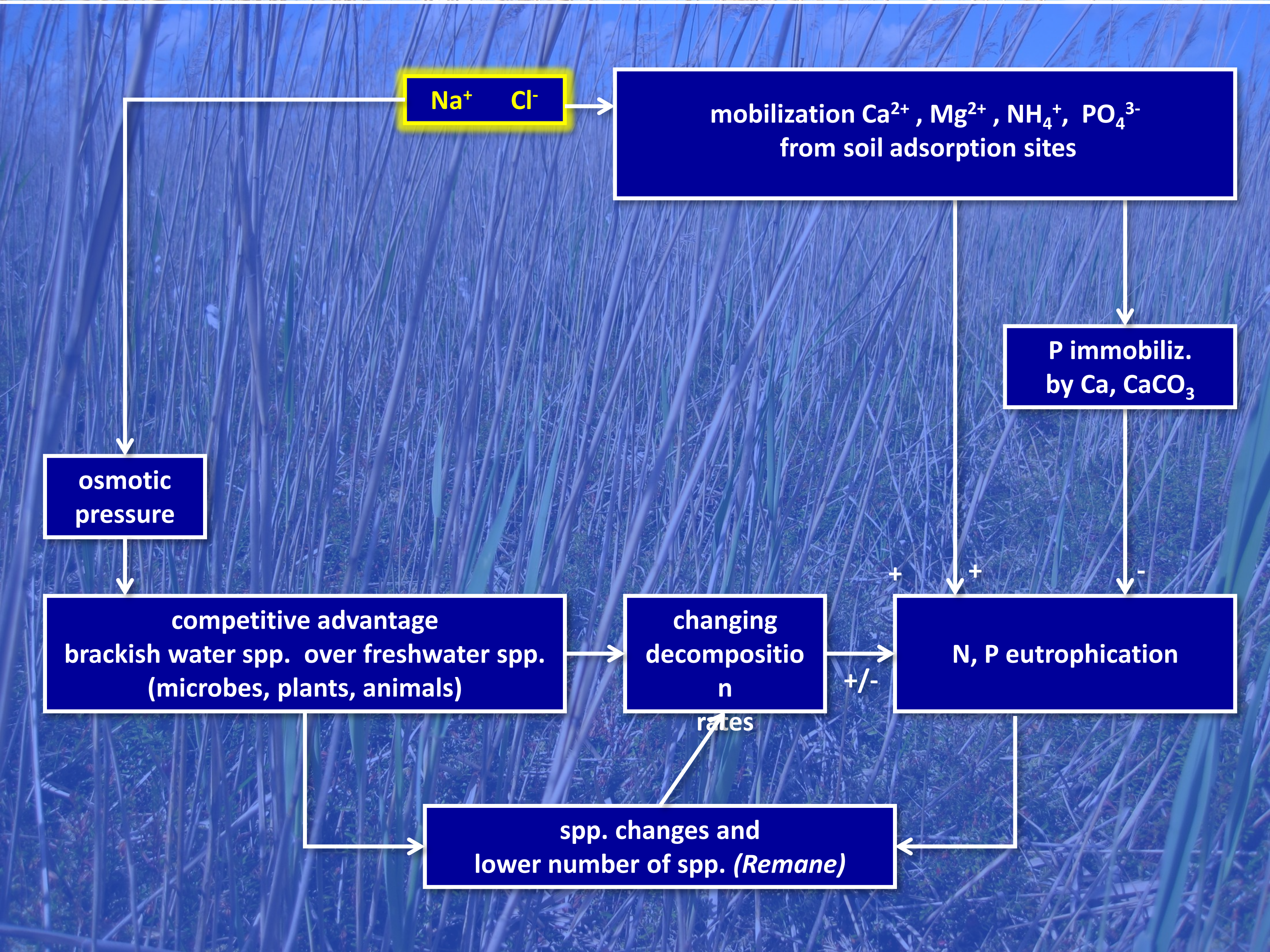
Loeb et al., in prep.
Miletto et al. Microb. Ecol. 2010


Mg+2
H+
Ca+2
K+
H+
Na+
Clay or humus particle
NH4+
NH4+
Ca+2
Na+
K+
H+
Mg+2
forum.grasscity.com
Soil solution


Cl-
Phosphate ions
Me(OH)3
Cl-
Cl-
Soil solution
www.life-treasure.com



Na+ Cl-
mobilization Ca2+ , Mg2+ , NH4+, PO43-
from soil adsorption sites
osmotic
pressure
competitive advantage
brackish water spp. over freshwater spp.
(microbes, plants, animals)
changing
decompositio
n
rates
+
+
-
+/-
N, P eutrophication
spp. changes and
lower number of spp. *(Remane)*


Na+ Cl-
mobilization Ca^{2+}, Mg^{2+}, NH_4^+, PO_4^{3-}
from soil adsorption sites
P immobiliz.
by Ca, $CaCO_3$
osmotic
pressure
+
+
-
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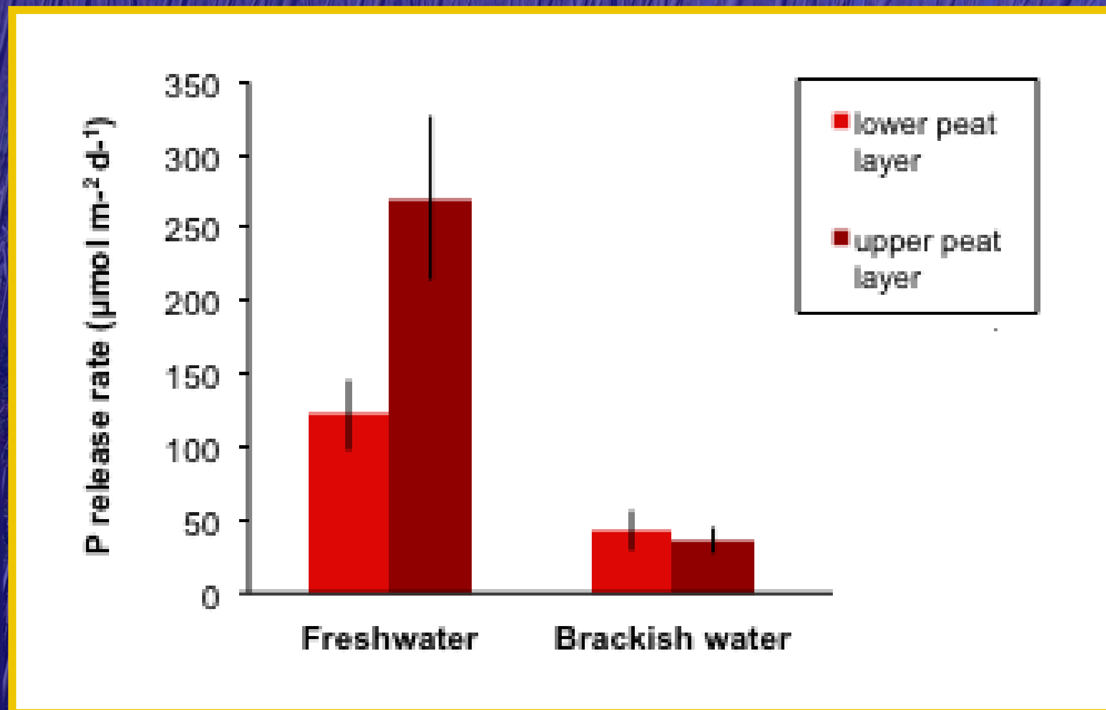
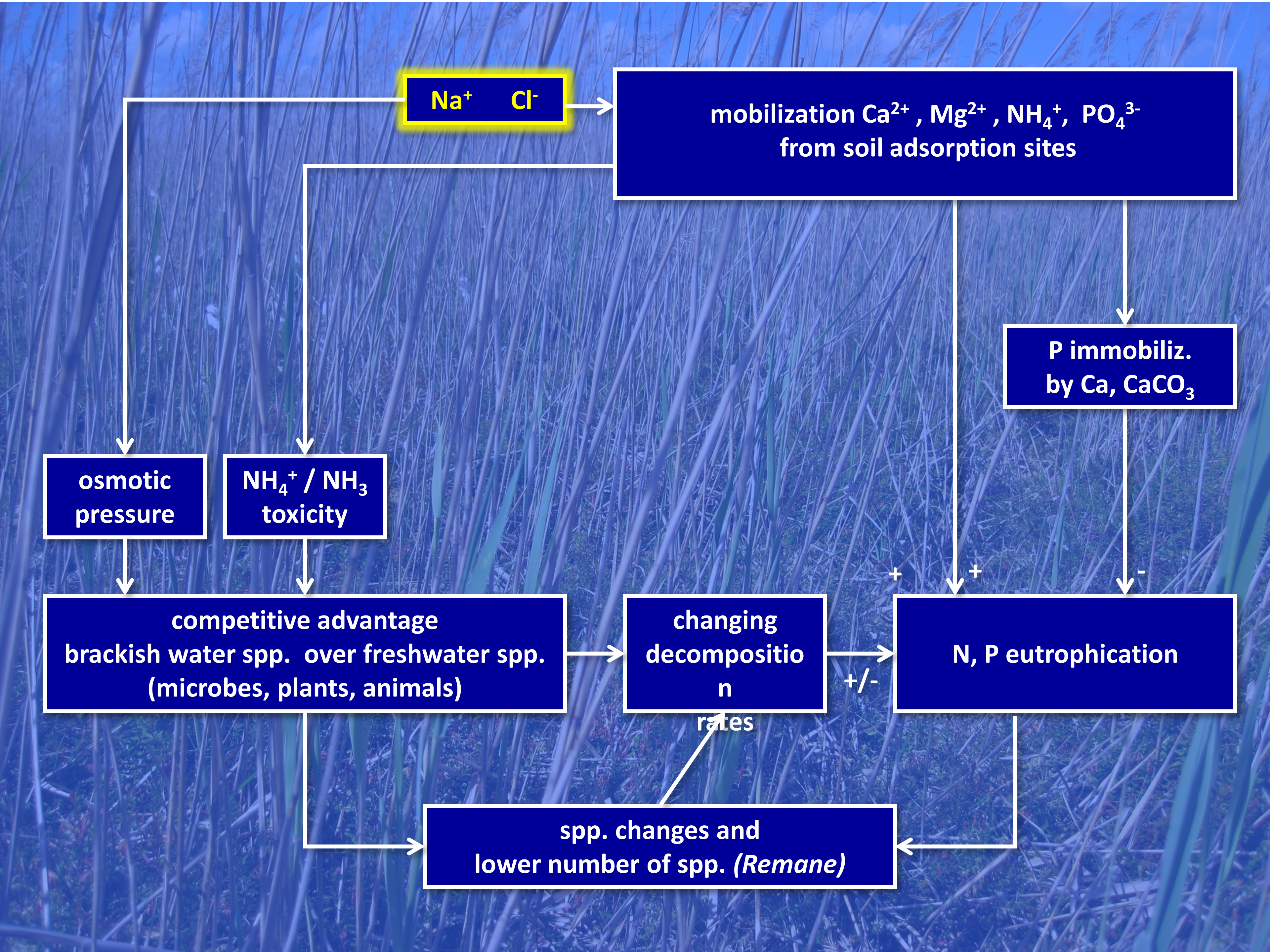


after 1.5 months 0.7 g Cl L^{-1}

Van Diggelen et al. in prep.

(N.B., see also poster 231!)



Na^+ Cl^-
mobilization Ca^{2+}, Mg^{2+}, NH_4^+, PO_4^{3-} from soil adsorption sites
P immobiliz. by Ca, $CaCO_3$
osmotic pressure
NH_4^+ / NH_3 toxicity
competitive advantage brackish water spp. over freshwater spp. (microbes, plants, animals)
changing decompositio n rates
N, P eutrophication
+
+
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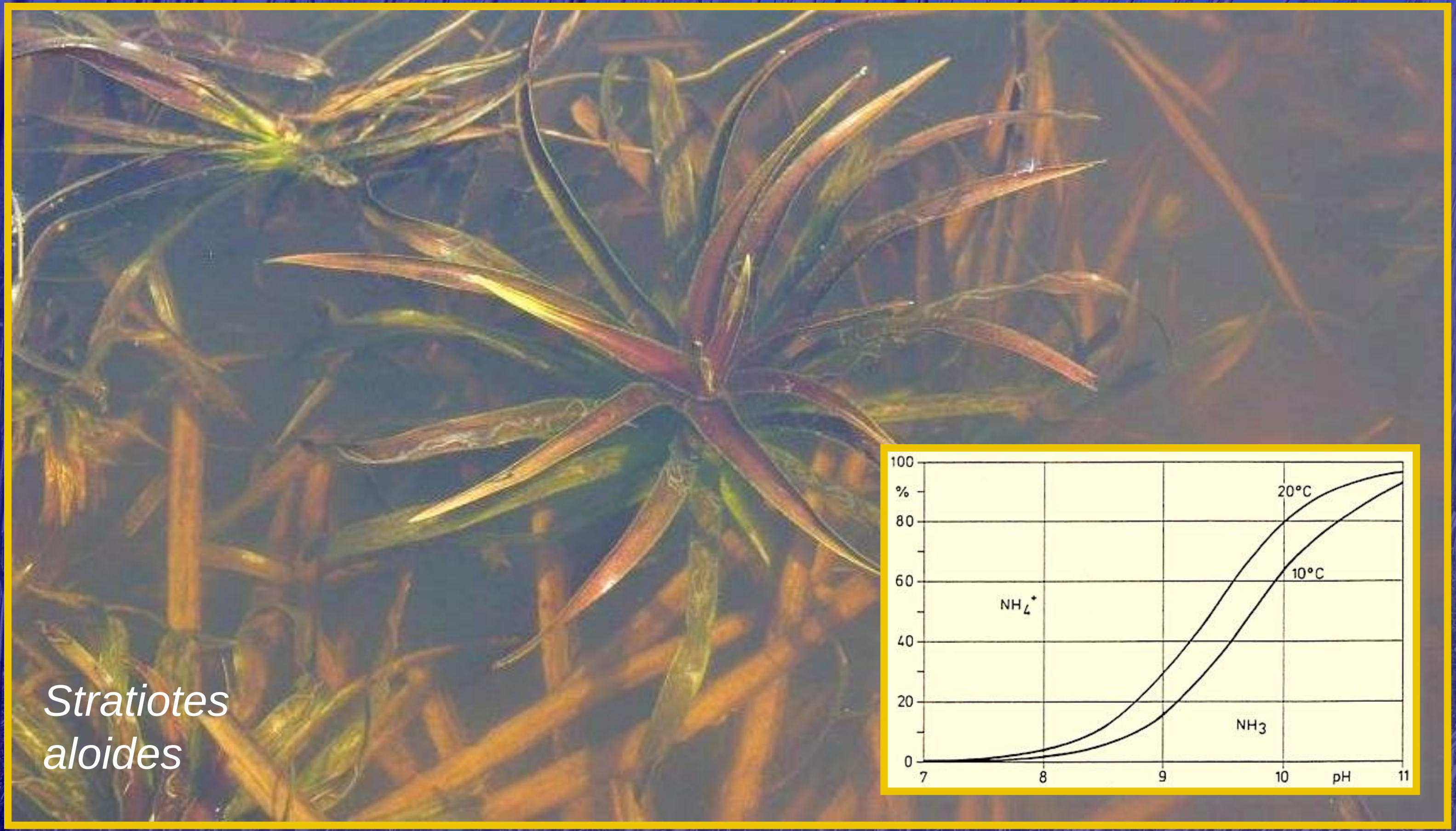
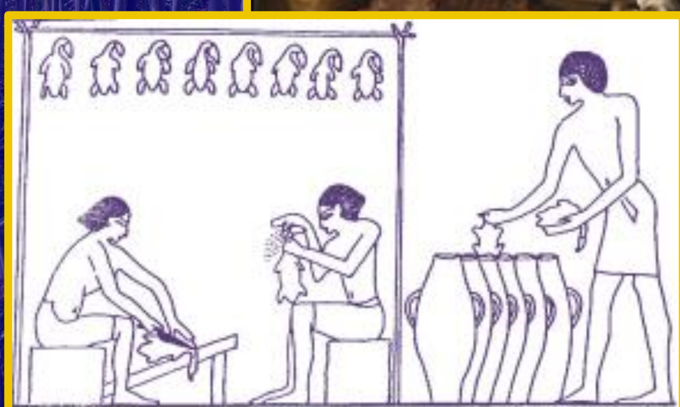
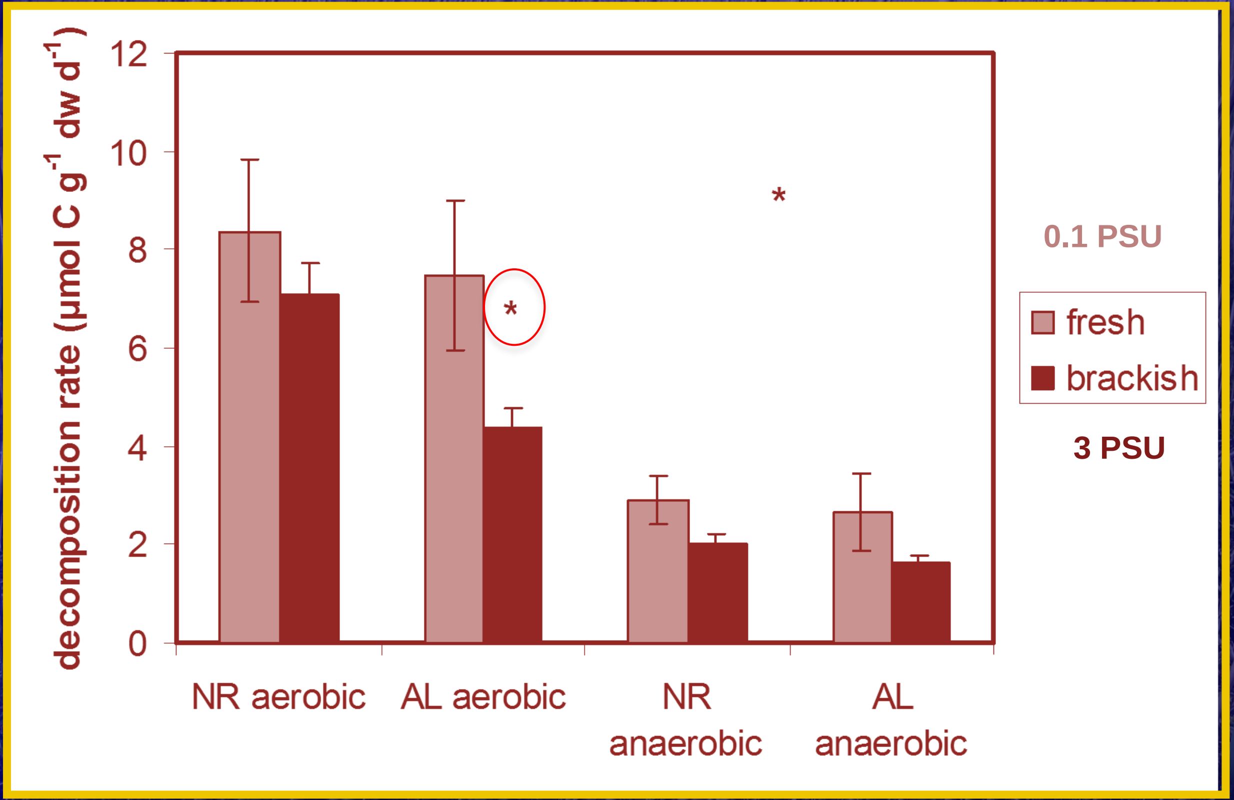


NH_4^+ (µmol L^{-1})	1980	1992
Vital plants:	5.4 (2.5-6.3)	7.5 (5.7-8.2)
Non-vital plants:	19.2 (1.8-93.8)	† 40.9 (6.5-74.6)

Smolders 1995



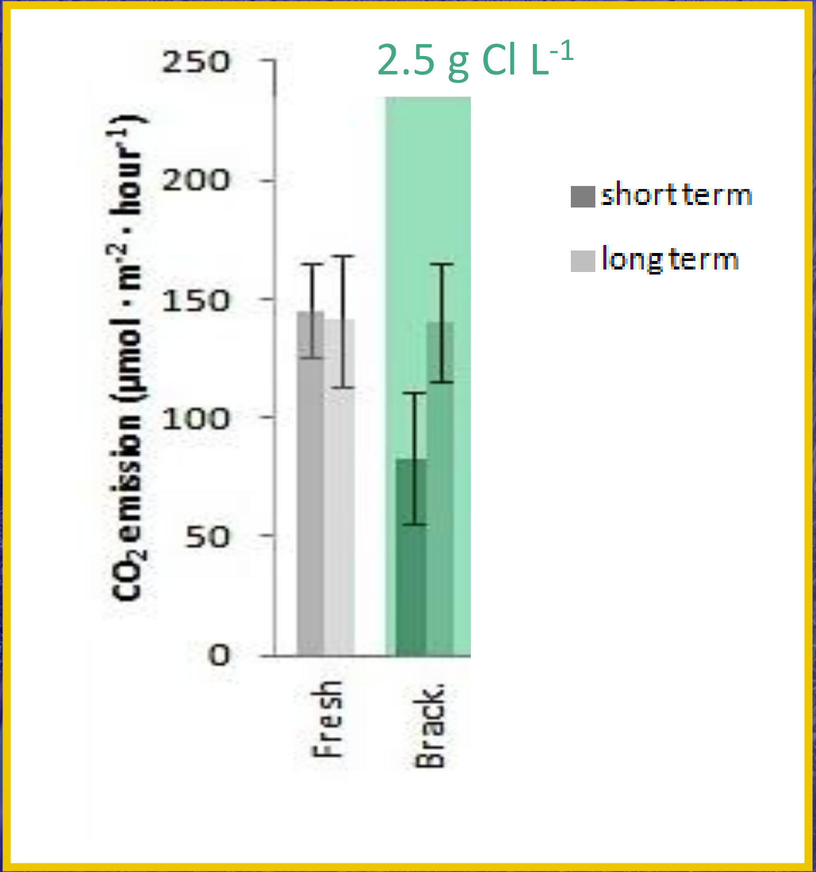
Wtewael 1620

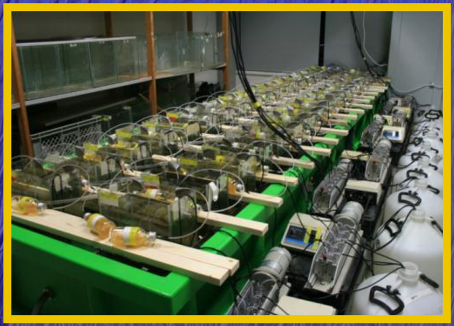


NR = nature reserve
AL = agricultural land

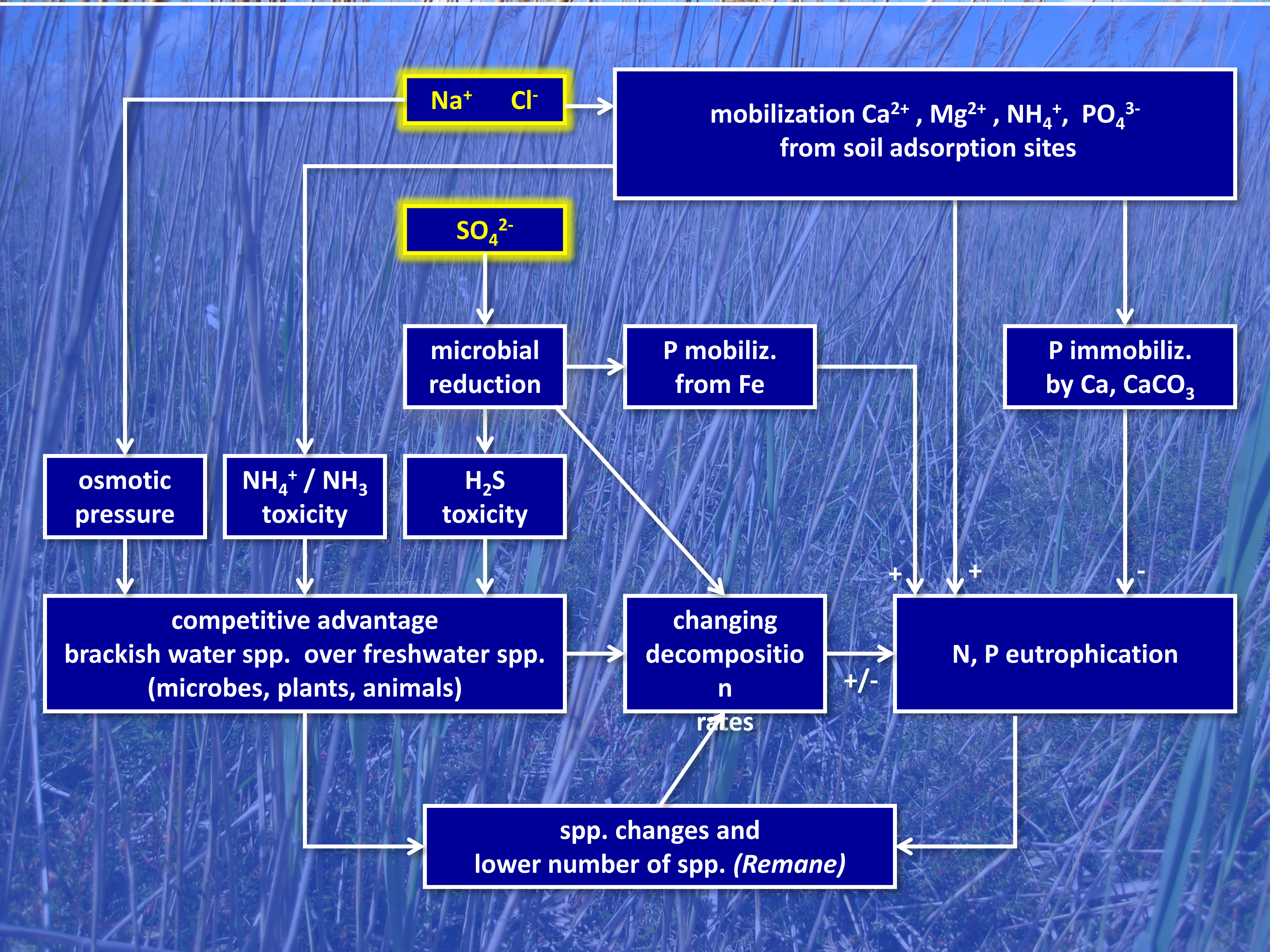
Loeb et al., in prep

Time
Ecosystem





Van Dijk et al, in prep.



Na^+ Cl^-
mobilization Ca^{2+} , Mg^{2+} , NH_4^+, PO_4^{3-}
from soil adsorption sites
SO_4^{2-}
microbial reduction
P mobiliz. from Fe
P immobiliz. by Ca, $CaCO_3$
osmotic pressure
NH_4^+ / NH_3 toxicity
H_2S toxicity
+
+
-
competitive advantage
brackish water spp. over freshwater spp.
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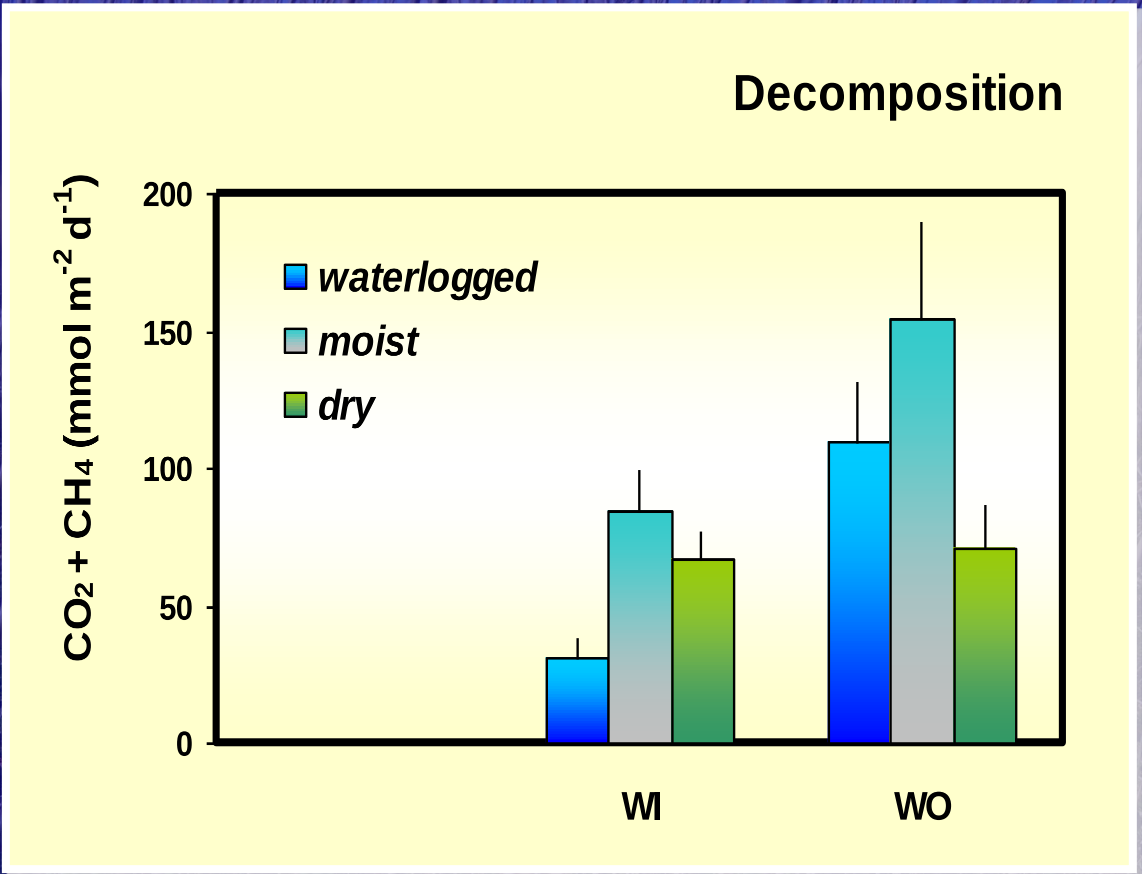
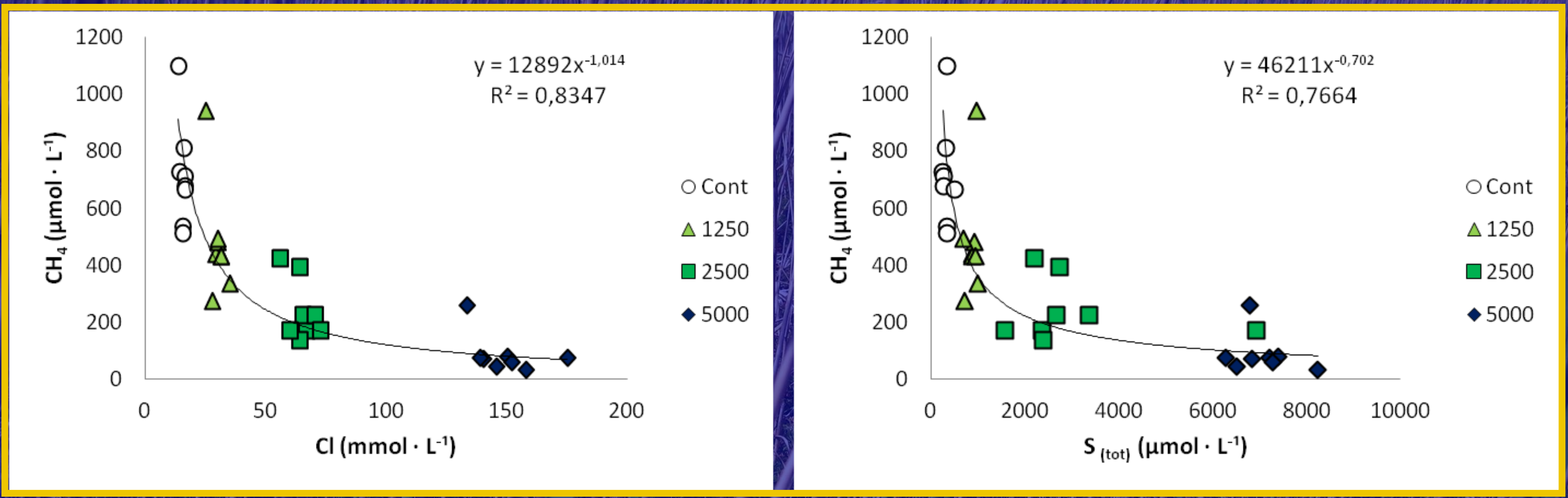
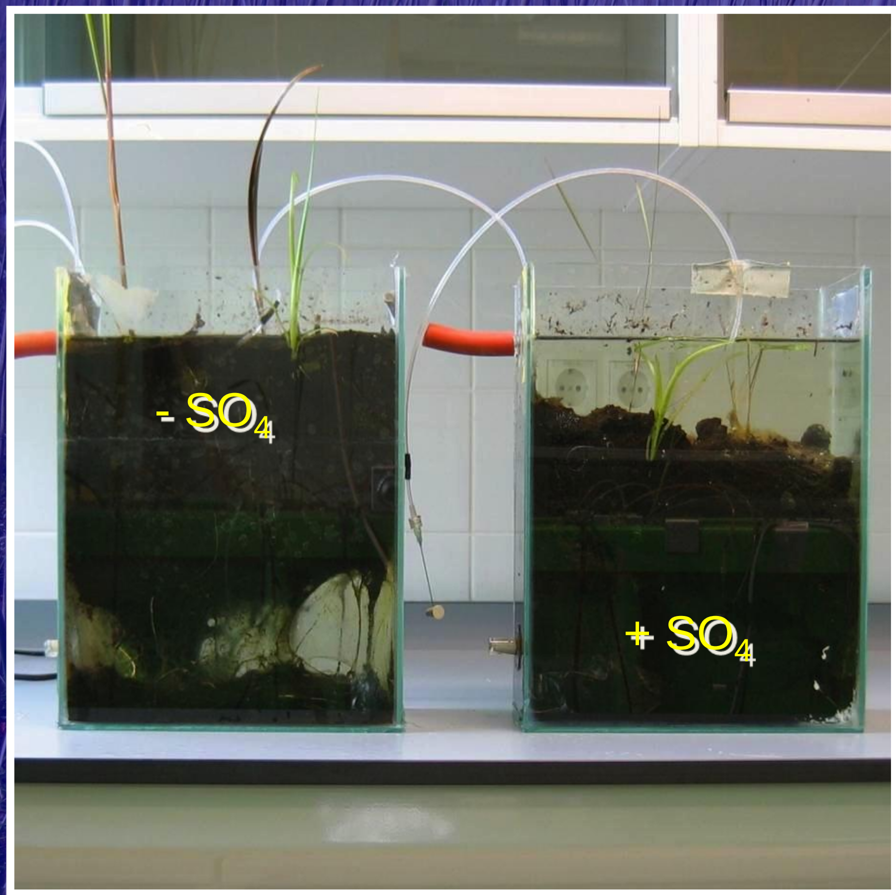


SO_4^-, AVS: low high

Lamers et al PhD Thesis 2001
Lamers et al in prep.



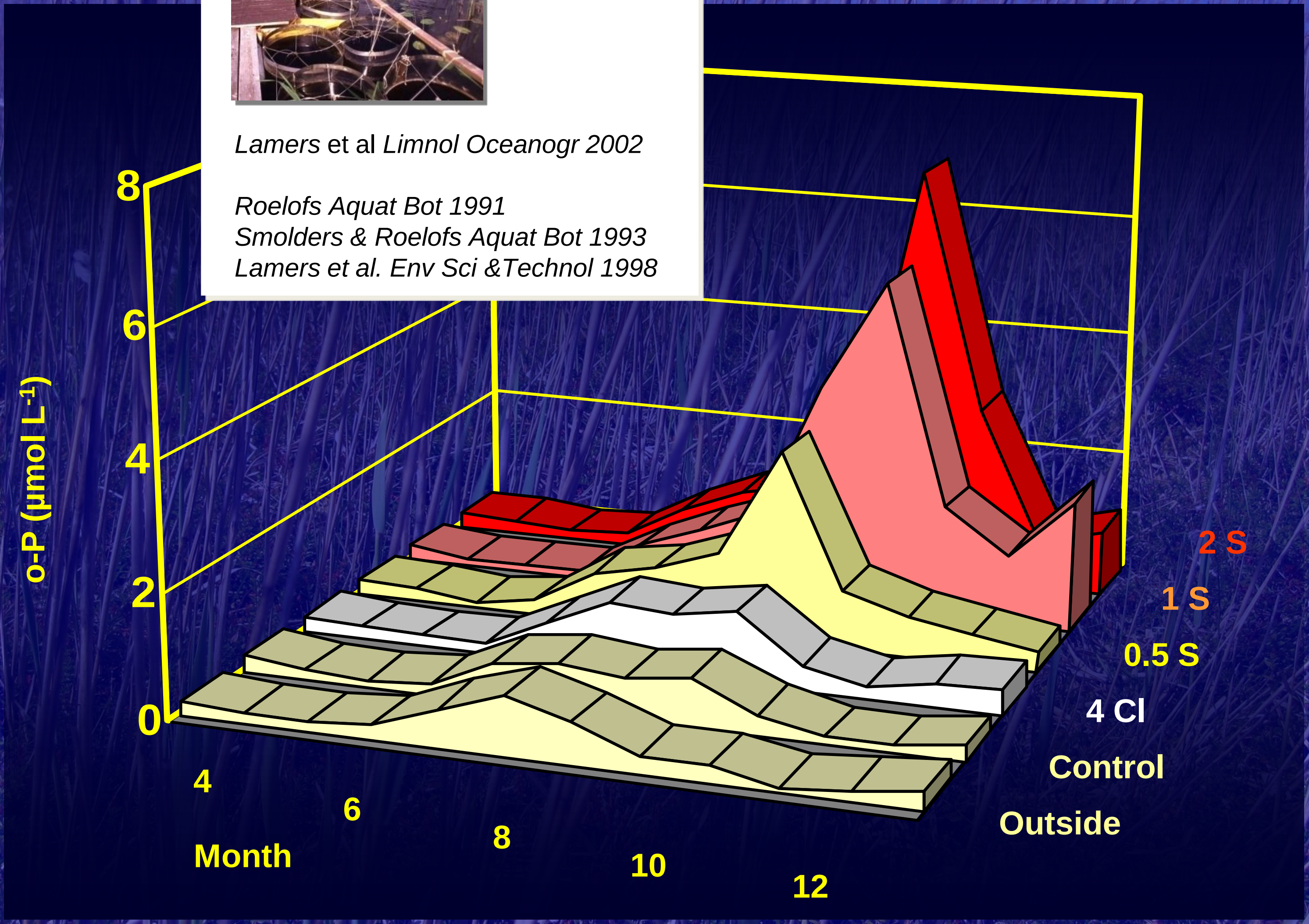
Van Dijk et al, in prep.



Lamers et al J Ecol 1999

Smolders et al J Appl Ecol 2002
Tomassen et al Biogeochem 2004

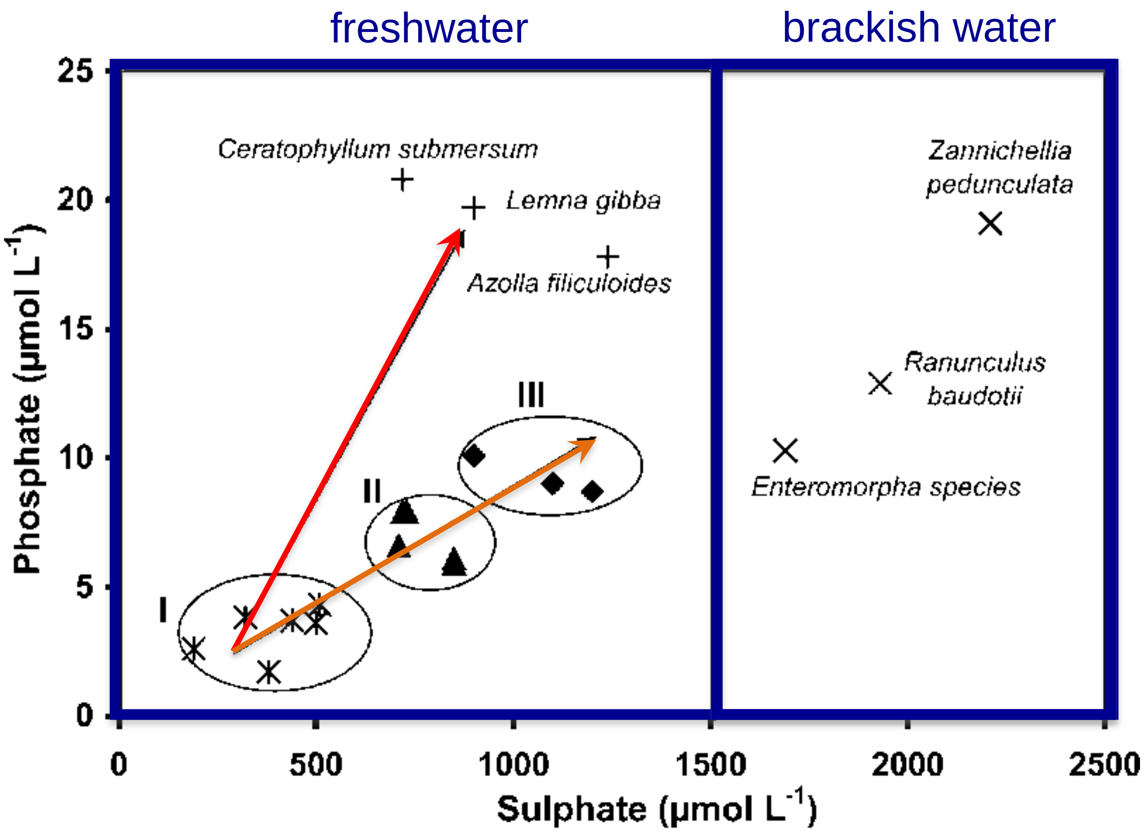
Loeb et al. Biogeochem 2007



Lamers et al *Limnol Oceanogr 2002*

Roelofs Aquat Bot 1991
Smolders & Roelofs Aquat Bot 1993
Lamers et al. Env Sci &Technol 1998

Sulfate (mM) enrichment: P-mobilization and/or sulfide toxicity



I ***Stratiotes aloides***
Hydrocharis morsus ranae
Potamogeton acutifolius
Potamogeton compressus
Potamogeton lucens
Utricularia vulgaris

II ***Nymphoides peltata***
Ranunculus circinatus
Spirodela polyrhiza
Lemna trisulca
Potamogeton mucronatus

III ***Potamogeton pectinatus***
Myriophyllum spicatum
Ceratophyllum demersum

Smolders et al. Chem Ecol 2006

Everglades

Lower OM
Ca ~ P
Lower P

European lowland peatland

Higher OM
Fe ~ P
Higher P

fertilized

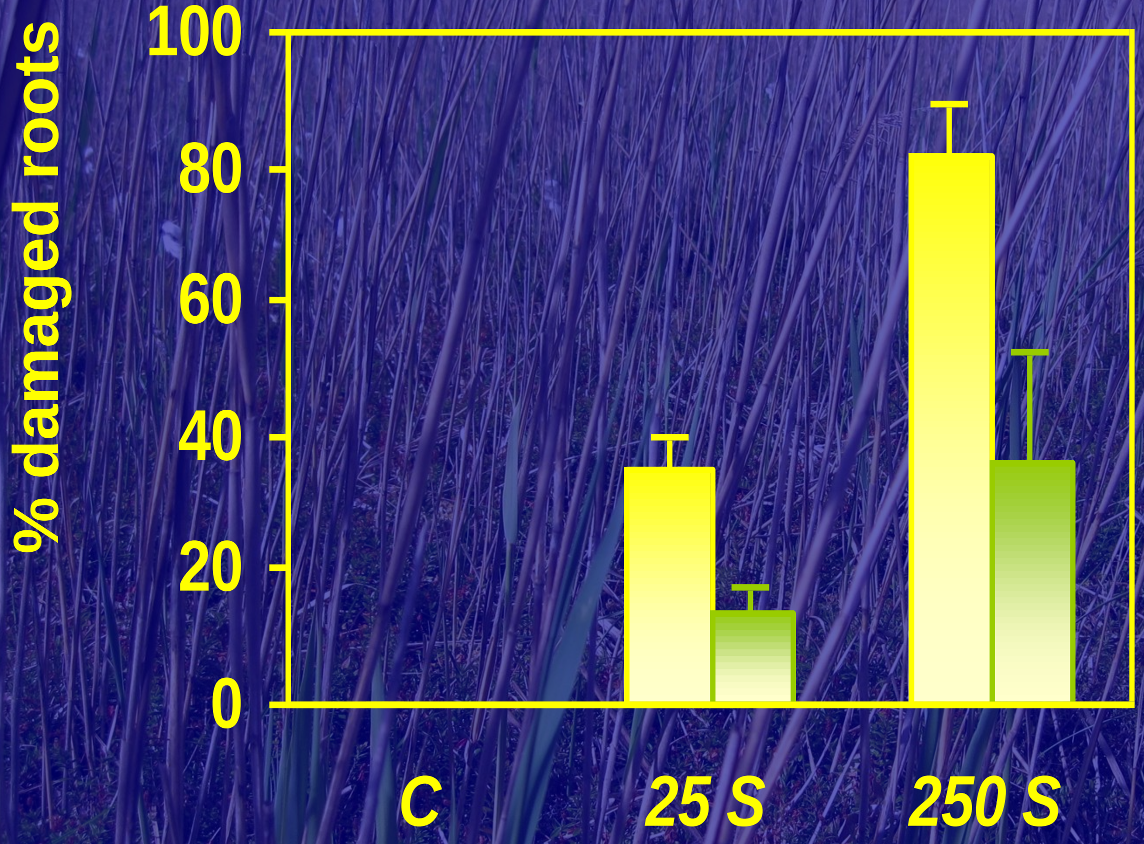
fertilized + sulfate

April May June July September

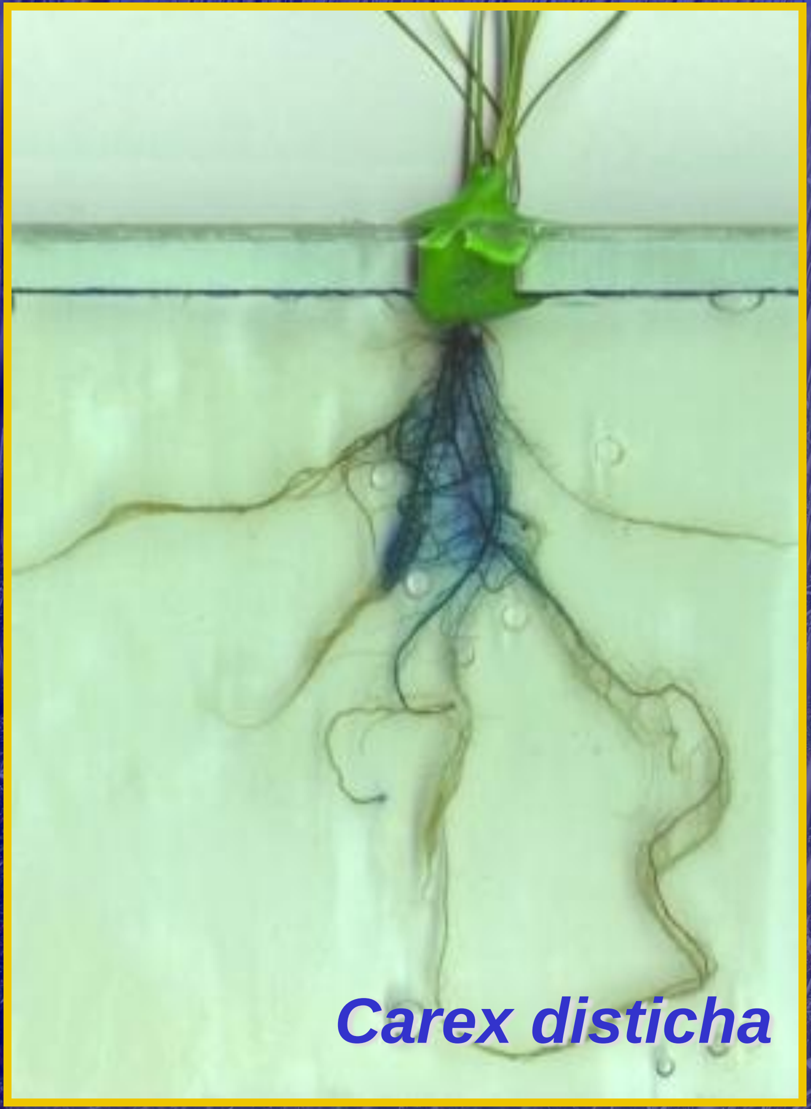
November September July 2006 July 2005

Geurts et al. Environ Pollut 2009


Lamers subm



Lamers et al. subm.



Lamers et al. subm.

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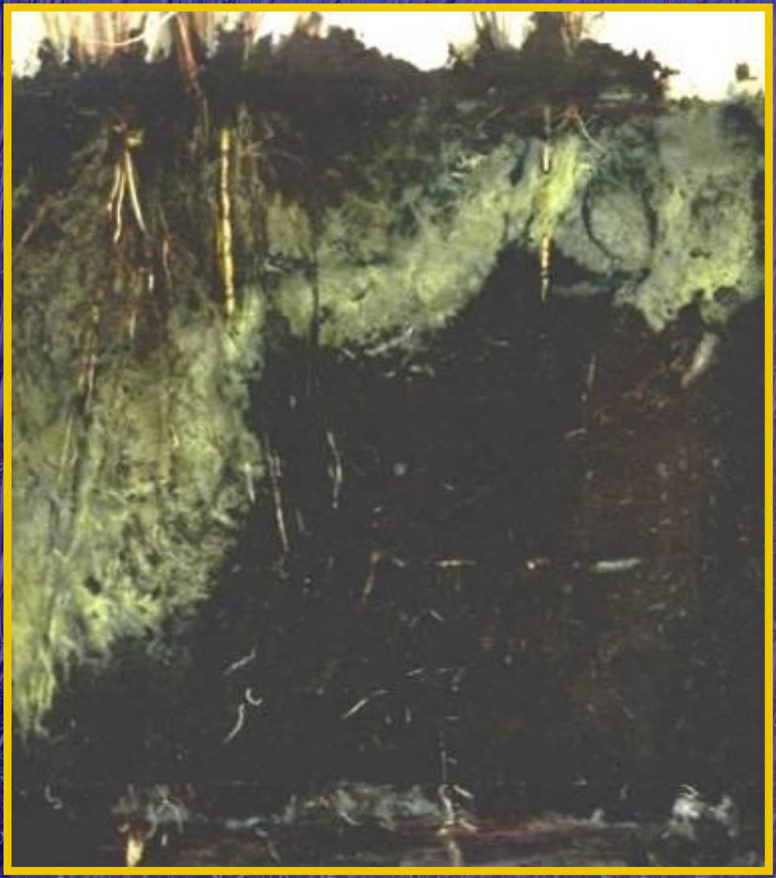

Control ***Sulfide treatment***

Lamers et al. Frontiers Microbiol 2012

Wetland type *Species*	Concentration ($\mu mol\ l^{-1}$)	Observation	Method	Reference
Seagrass meadows				
Halodule wrightii	2000	AD	glucose add. to increase SO_4 red.	Koch *et al.*, 2007
Posidonia oceanica	>1800	AD	glucose add. to increase SO_4 red.	Frederiksen *et al.* 2008
Thalassia testudinum	6000	AD (only high T & Sal.)	H_2S in hydroponic culture	Koch & Erskine, 2001
Thalassia testudinum	5500	AD	glucose add. to increase SO_4 red.	Koch *et al.*, 2007
Thalassia testudinum	>500	AD	field observation	Borum *et al.*, 2004
Zostera marina	600 / 1000	NP (low / high light)	H_2S inject. microcosm sediment	Goodman *et al.*, 1995
Zostera marina	>1800	no indication of AD	glucose add. in field to increase SO_4 red.	Frederiksen *et al.* 2008
Salt mashes				
Spartina alterniflora	1130	AP, RD	H_2S in hydroponic culture	Koch & Mendelssohn, 1989
Spartina alterniflora	2000-3000	AP, RA, NU	H_2S in hydroponic culture	Koch *et al.*, 1990
Mangroves				
Avicennia marina (sl)	500-1000	AP, RP	H_2S inject. microcosm sediment	McKee, 1993
Avicennia marina	>4000		field observation	McKee, 1993
Rhizophora mangle (sl)	>1000		H_2S inject. microcosm sediment	McKee, 1993
Rhizophora mangle	>1000		field observation	McKee, 1993
Freshwater aquatic				
Ceratophyllum demersum	>500	AP	SO_4 addition mesocosms	Geurts *et al.*, 2009
Elodea nutallii	100	AP	SO_4 addition enclosures	Van der Welle *et al.*, 2007a
Elodea nutallii	150-500	AP	SO_4 addition mesocosms	Geurts *et al.*, 2009
Hydrilla verticulata	100	NP	H_2S in root hydroponic culture	Wu *et al.*, 2009
Nitella flexilis	50	AP	H_2S injection aquarium sediment	Van der Welle *et al.*, 2006
Potamogeton compressus	150-500	AP	SO_4 addition mesocosms	Geurts *et al.*, 2009
Statiotes aloides	10-100	RD	H_2S in root hydroponic culture	Smolders & Roelofs, 1996
Stratiotes aloides	500	AP	SO_4 addition mesocosms	Geurts *et al.*, 2009
Stratiotes aloides	100-600	AP	SO_4 addition enclosures	Van der Welle *et al.*, 2007a
Freshwater wetlands				
Calamagrostis epigejos (sl)	30-50	AP	natural production in microcosm	Grootjans *et al.*, 1997
Calla palustris	150	AP	SO_4 addition mesocosms	Geurts *et al.*, 2009
Caltha palustris	170	AP, Y	H_2S injection microcosm sed.	Van der Welle *et al.*, 2007b
Carex disticha	10-20	AP	SO_4 addition mesocosms	Lamers *et al.*, 1998
Carex disticha	25	LC, RD	H_2S injection microcosm sed.	Lamers *et al.*, this study
Carex nigra	10-20	AP	SO_4 addition mesocosms	Lamers *et al.*, 1998
Cladium jamaicense	220 / 690 / 920	LE / NP / AD, RD	H_2S in hydroponic culture	Li et al., 2009
Equisetum fluviatile	50 / 500	AP (unfertilized/fertilized)	SO_4 addition mesocosms	Geurts *et al.*, 2009
Juncus acutiflorus	25 / 250	RD / AP	H_2S injection microcosm sed.	Lamers *et al.*, this study
Juncus alpinoarticulatusi (sl)	30-50	AP	natural production in microcosm	Grootjans *et al.*, 1997
Juncus effusus	500	AP	SO_4 addition mesocosms	Geurts *et al.*, 2009
Menyanthes trifoliata	150 / >150	AP (unfertilized/fertilized)	SO_4 addition mesocosms	Geurts *et al.*, 2009
Menyanthes trifoliata	>235	AP	field observation	Armstrong & Boatman, 1967
Panicum hemitomon	630	AP, RD	H_2S in hydroponic culture	Koch & Mendelssohn, 1989

Lamers et al. subm.

Salinity changes biogeochemistry and ecosystem functioning:

- ***Osmotic stress***
- ***Ionic strength, desorption, precipitation***
- ***Electron acceptor availability***
- ***Nutrient availability***
- ***Toxicity***

**Changes in community composition,
wetland biogeochemistry,
ecosystem functioning & services**

Temporal and spatial heterogeneity

€€ from NWO
Netherlands Organisation for Scientific Research

Thank you for your attention!