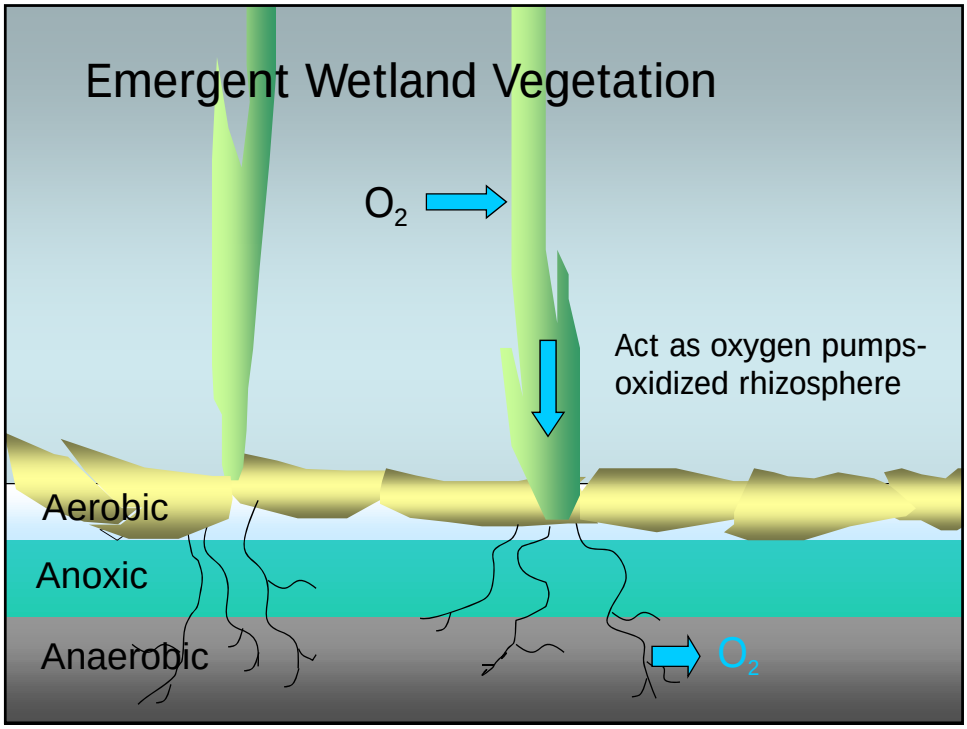
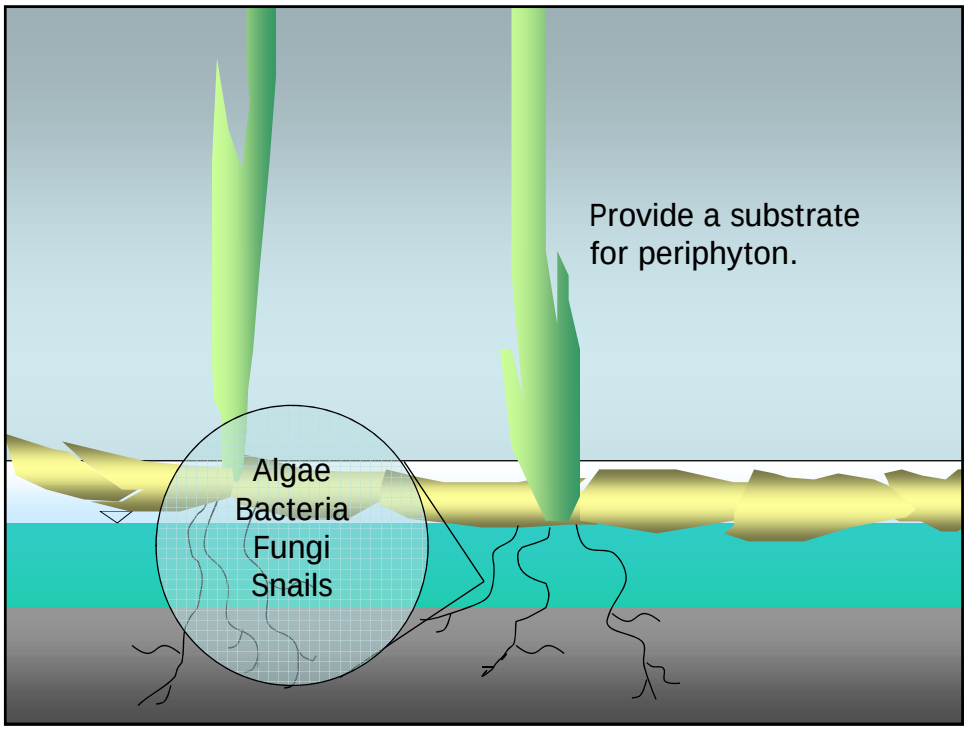
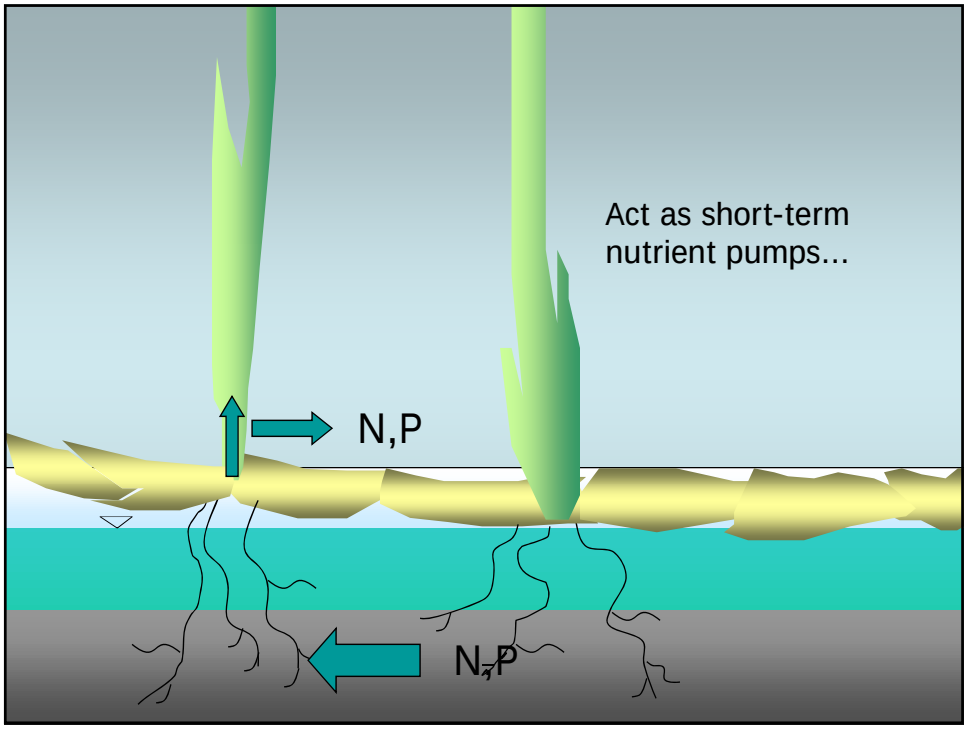
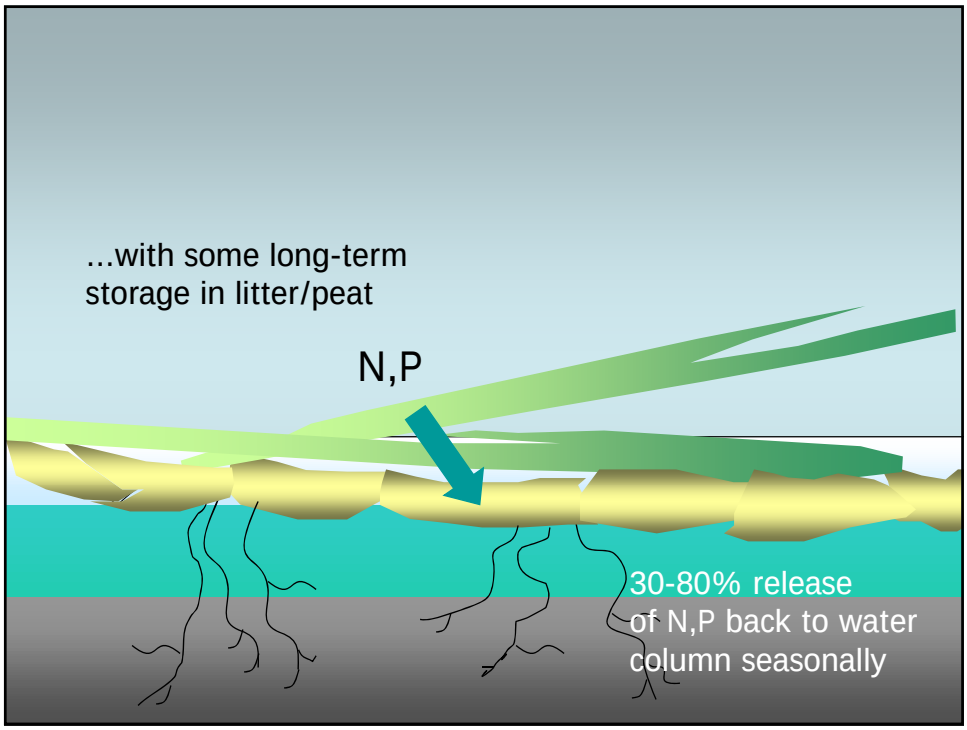
Nutrient Removal in Subsurface Flow Wetlands

- "Wetlands are a terrible way to remove phosphorus."
  (Jim Kriessl, 2000 Constructed Wetland Workshop, Arcata, Ca.)
- Phosphorus removal efficiencies were 98% in some subsurface flow wetlands
  (Mæhlum et al. 1995 and Geller 1997)

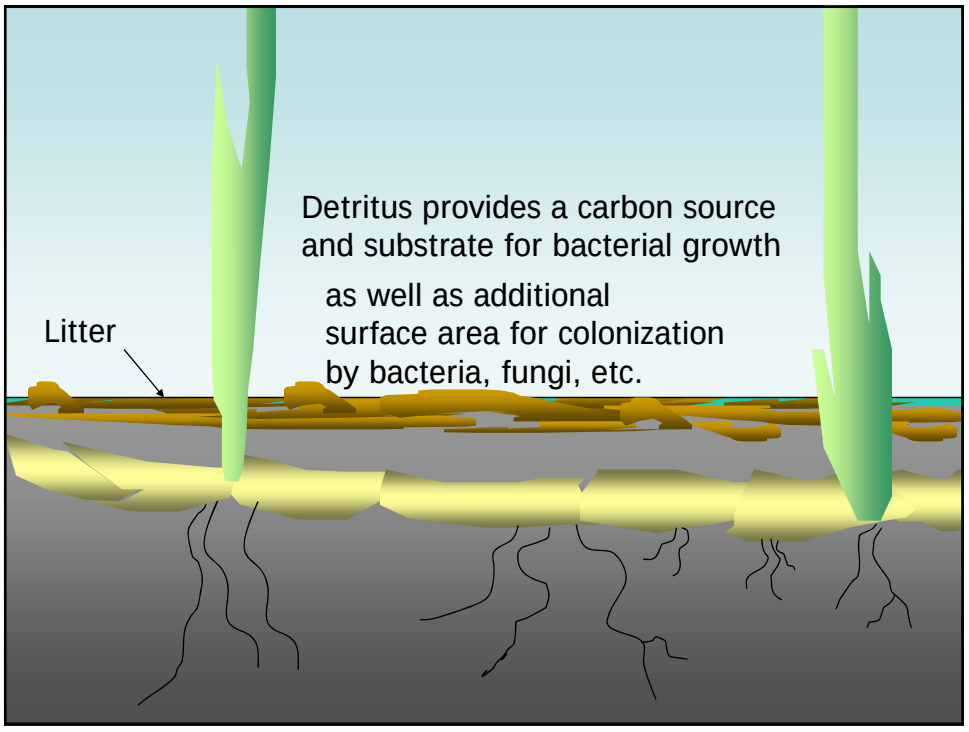

Emergent Wetland Vegetation
O_2
Act as oxygen pumps-
oxidized rhizosphere
Aerobic
Anoxic
Anaerobic
O_2

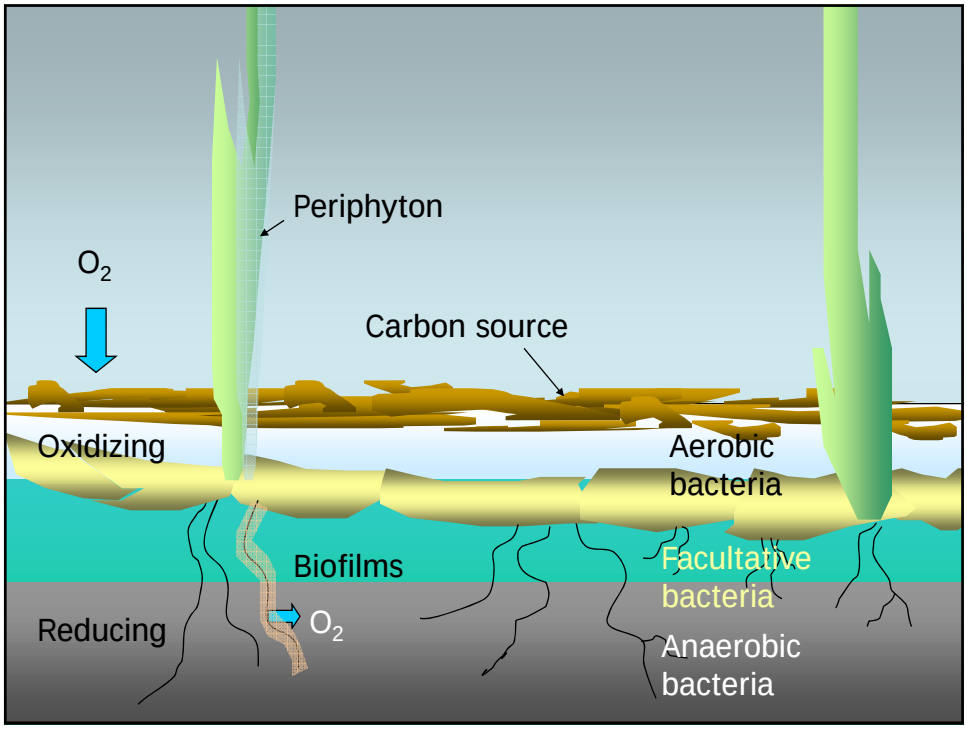

Provide a substrate
for periphyton.
Algae
Bacteria
Fungi
Snails

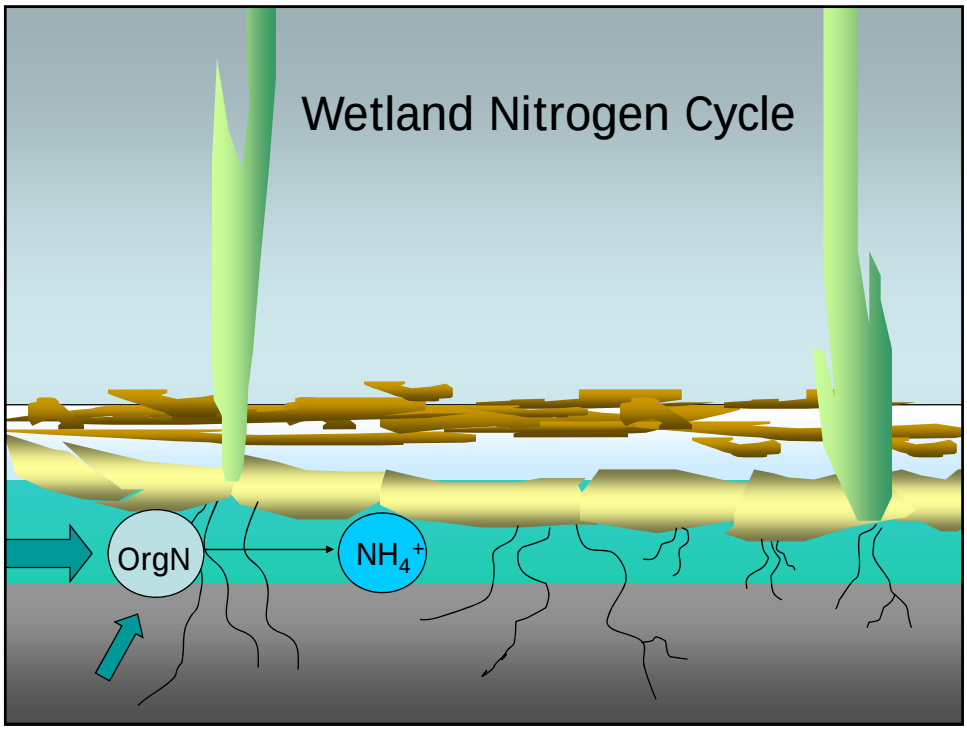

Act as short-term
nutrient pumps...
N,P
N,P

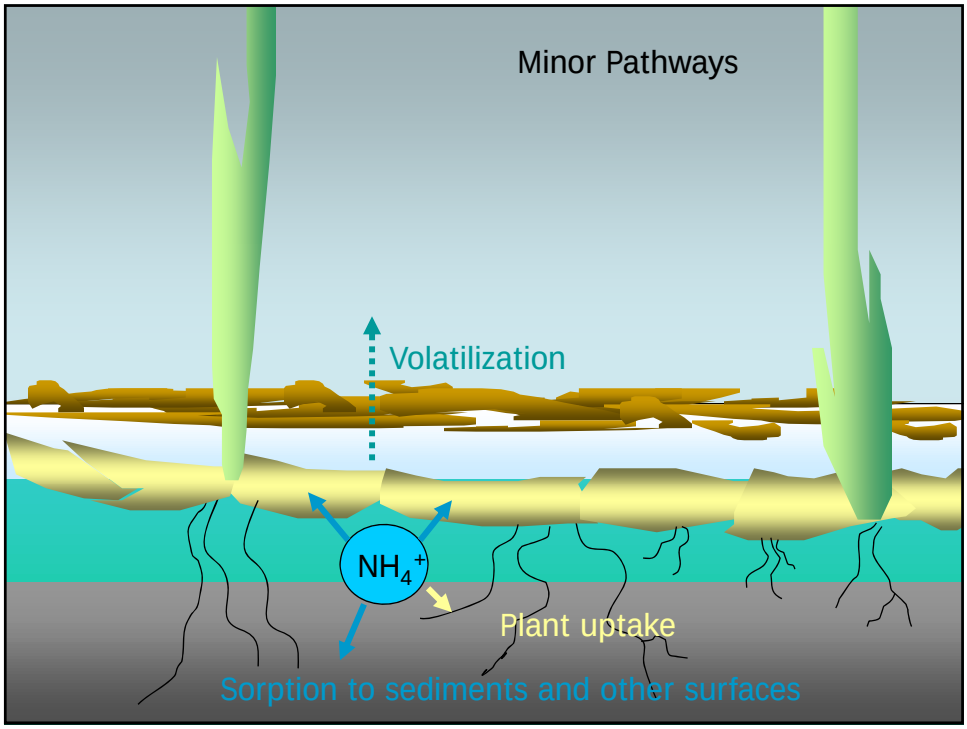

...with some long-term
storage in litter/peat
N,P
30-80% release
of N,P back to water
column seasonally

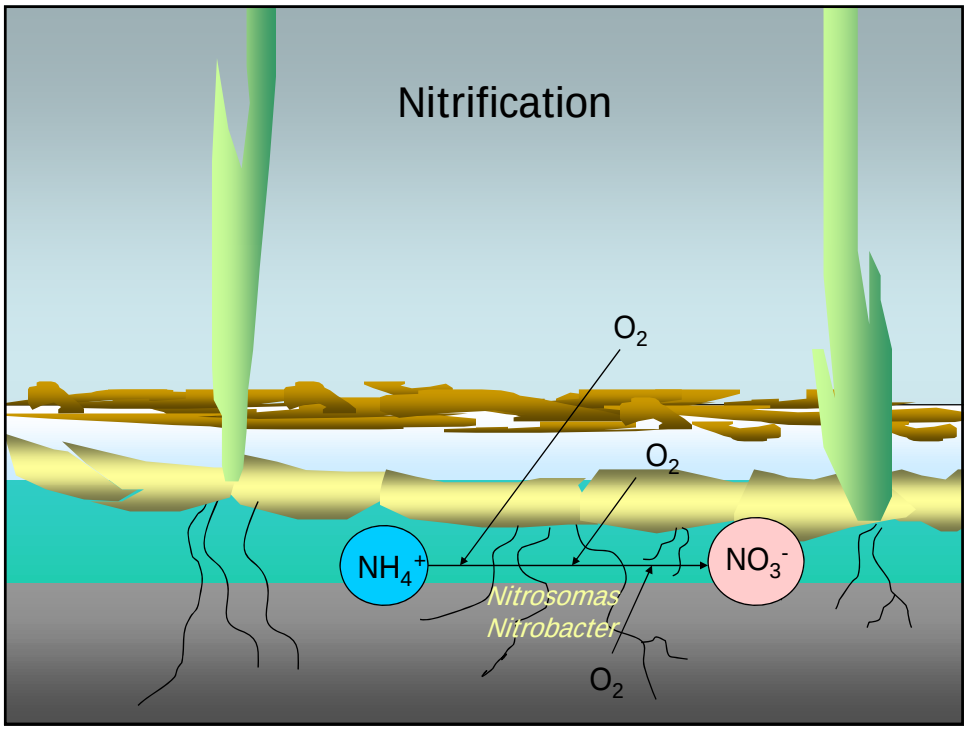
Dead vegetation forms the basis of the food web in nearly all NATURAL wetland ecosystems.

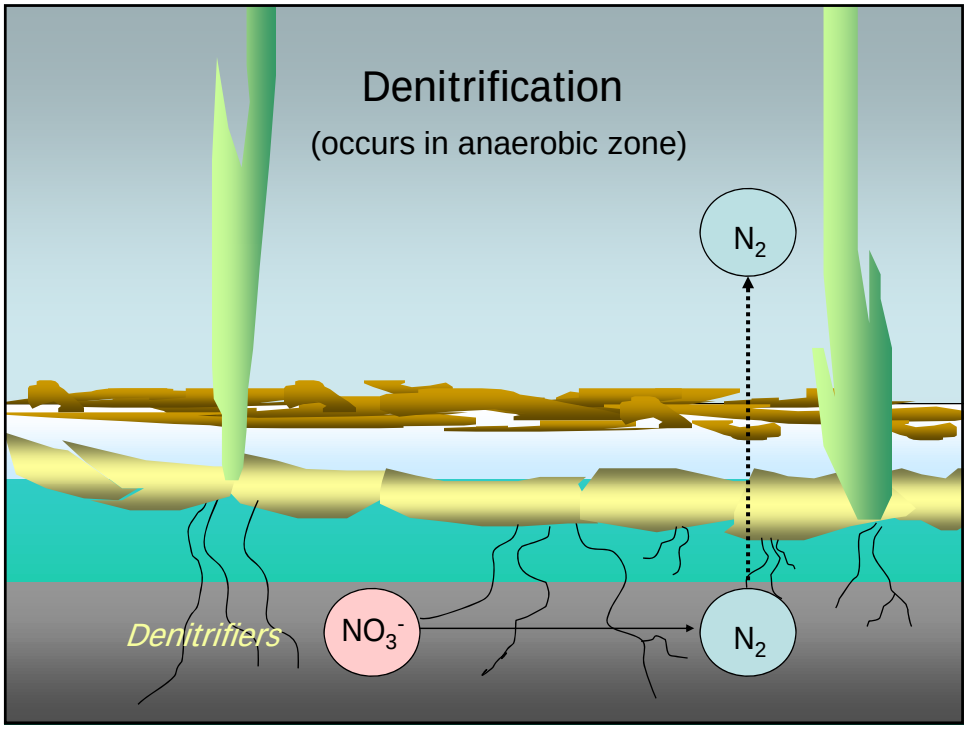



Periphyton
O_2
Carbon source
Oxidizing
Aerobic bacteria
Biofilms
Facultative bacteria
O_2
Reducing
Anaerobic bacteria


Wetland Nitrogen Cycle
OrgN
NH_4^+


Minor Pathways
Volatilization
NH_4^+
Plant uptake
Sorption to sediments and other surfaces


Nitrification
O_2
O_2
NH_4^+
NO_3^-
Nitrosomas
Nitrobacter
O_2

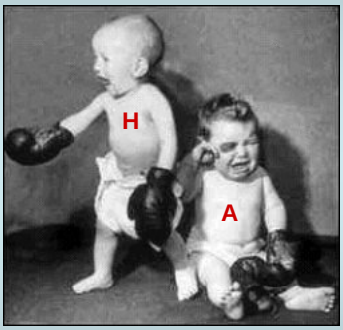


Nitrification is the rate limiting step in nitrogen removal from wetlands

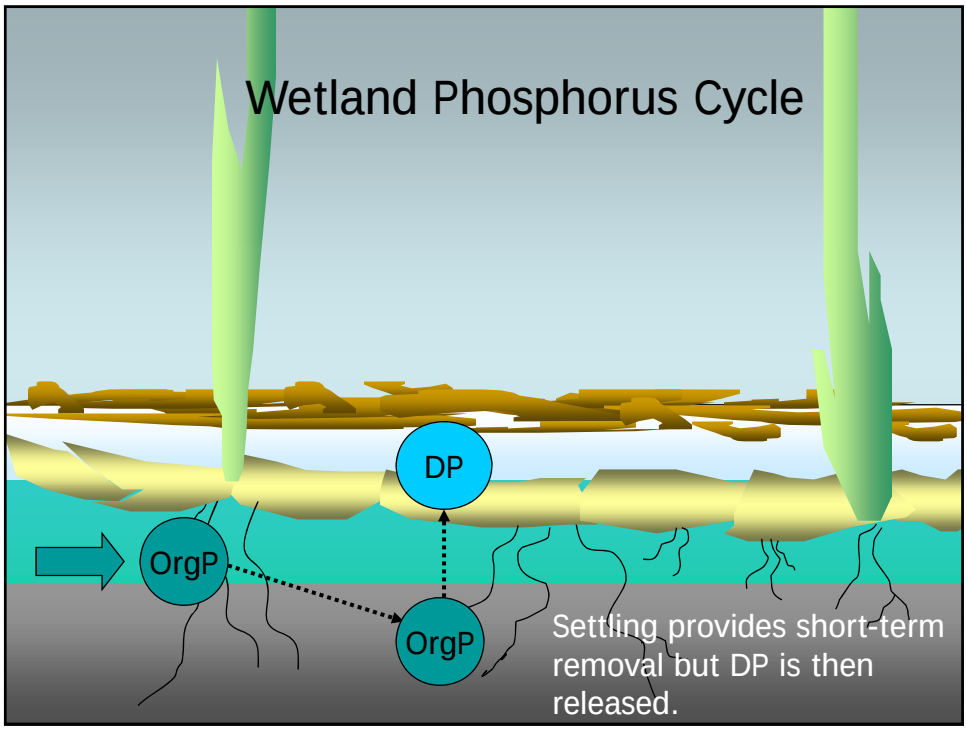
Nitrification is especially challenging in systems:

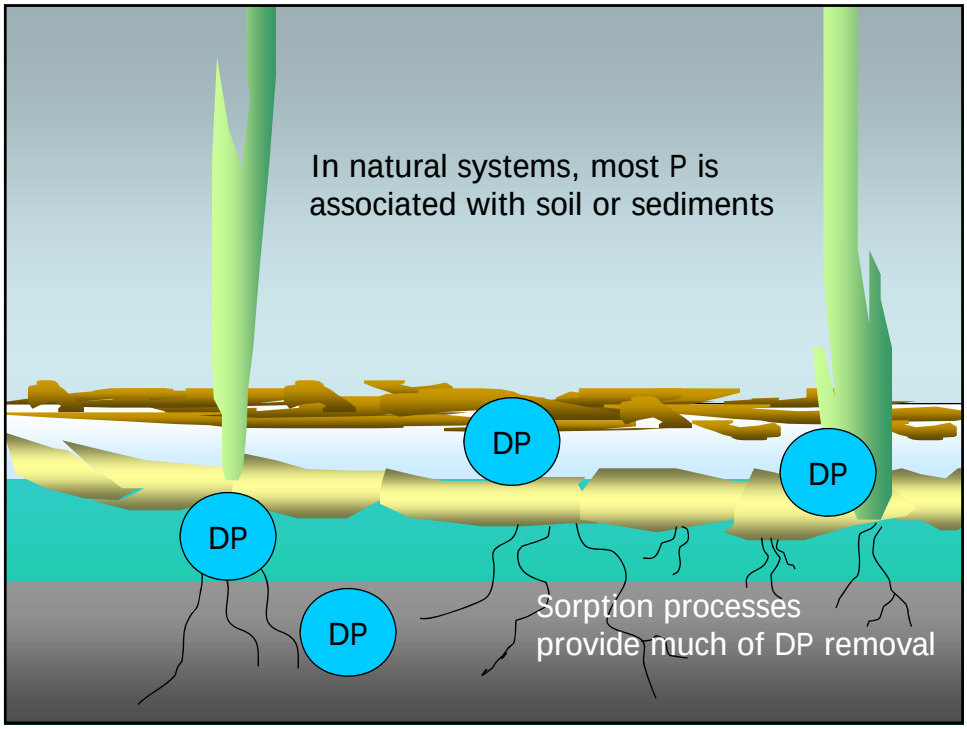
(1) with cold weather
(2) with low dissolved oxygen
(3) with high carbonaceous oxygen demand

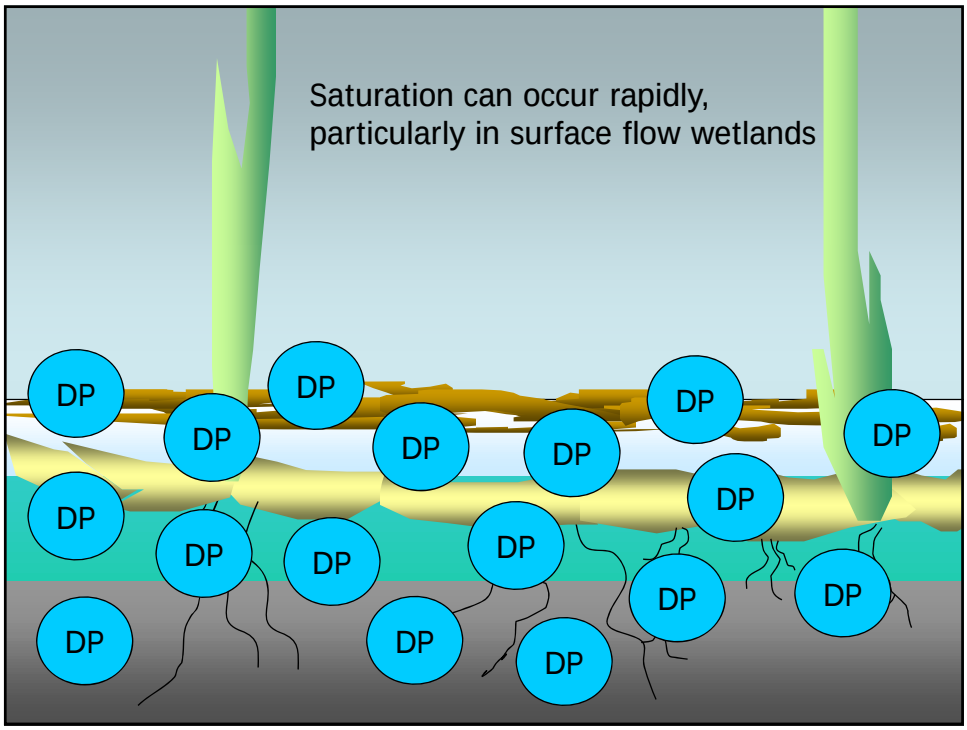
Heterotrophs outcompete nitrifiers (autotrophs) for available O_2



Although nitrification can proceed at D.O. of 0.3 mg/l, competition for available oxygen from heterotrophs can raise the D.O. requirement for initiation of nitrification to over 4 mg/l




In natural systems, most P is associated with soil or sediments
DP
DP
DP
DP
Sorption processes provide much of DP removal


Saturation can occur rapidly, particularly in surface flow wetlands
DP
DP
DP
DP
DP
DP
DP
DP
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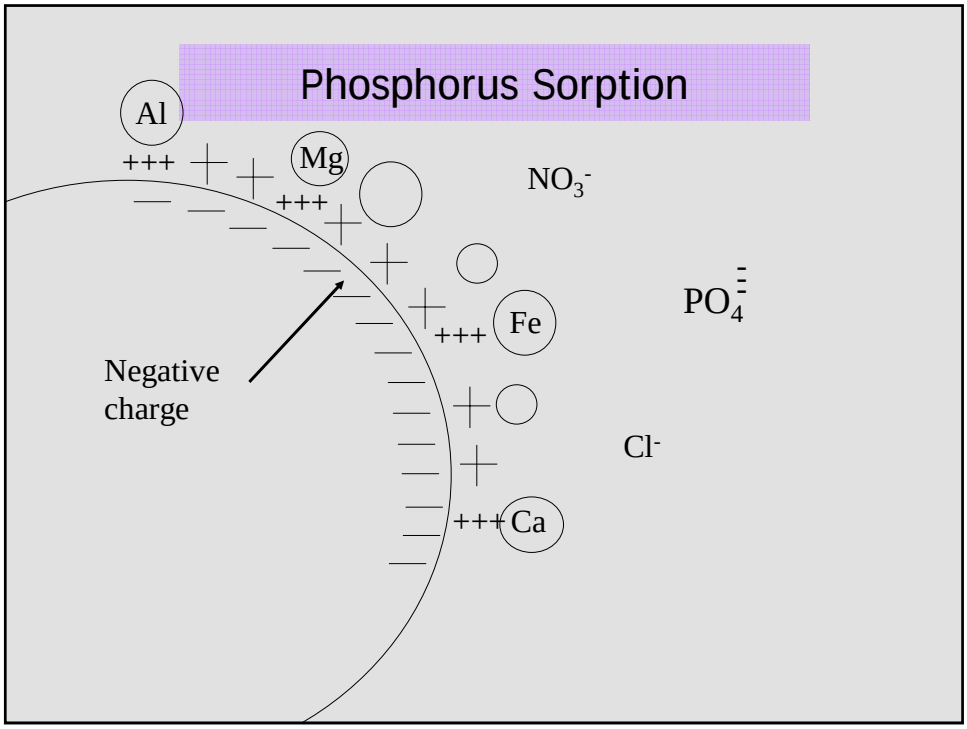
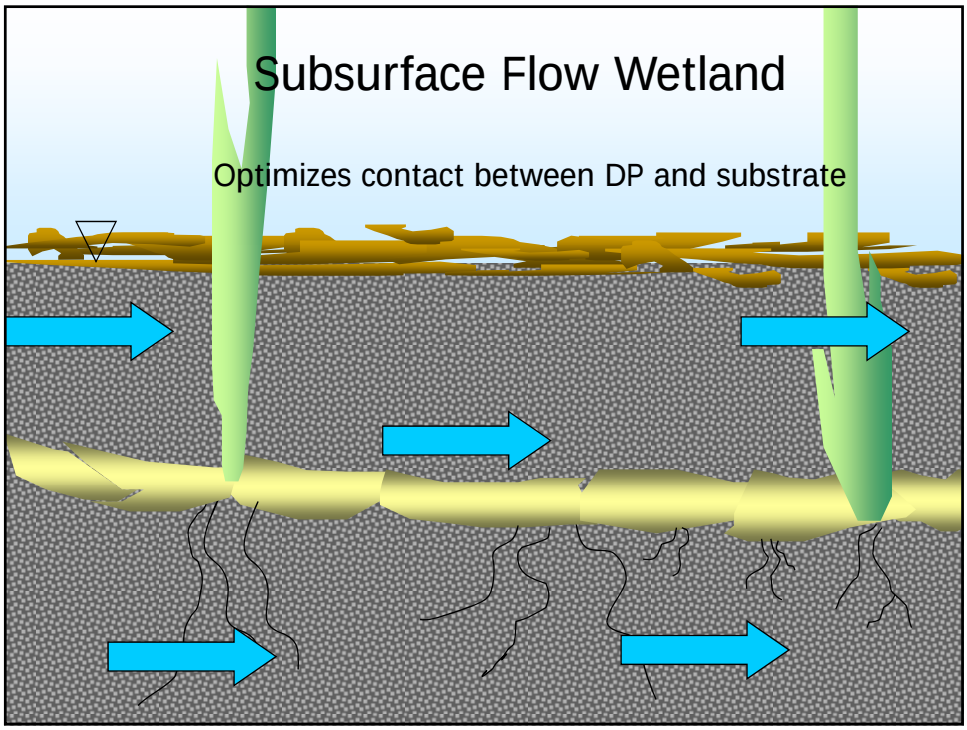
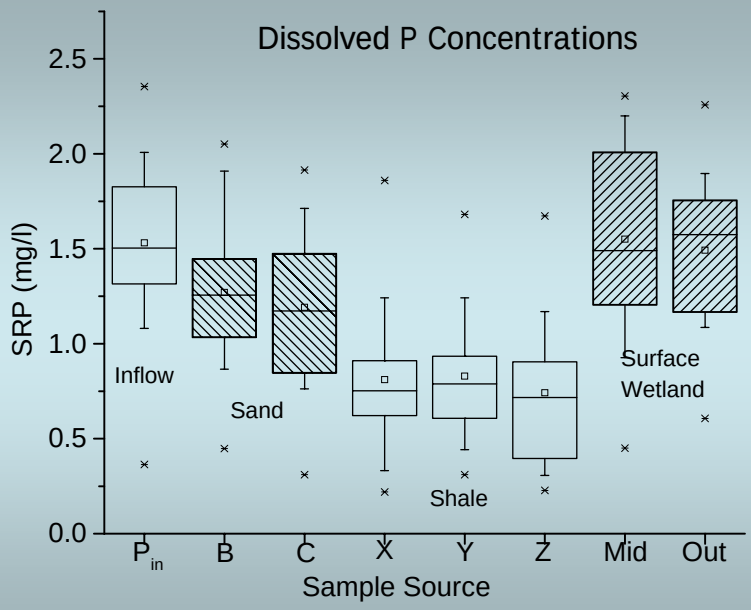
DP
DP
DP
DP
DP


Phosphorus Sorption
Al
+++
Mg
+++
NO_3^-
Fe
+++
$PO_4^{\equiv}$
Negative
charge
Cl^-
+++ Ca


Subsurface Flow Wetland
Optimizes contact between DP and substrate

Enhance P removal by using special substrates with high P sorption capacity and high hydraulic conductivity



Forbes et al. 2005. Envir. Sci. & Tech 39:4621-27

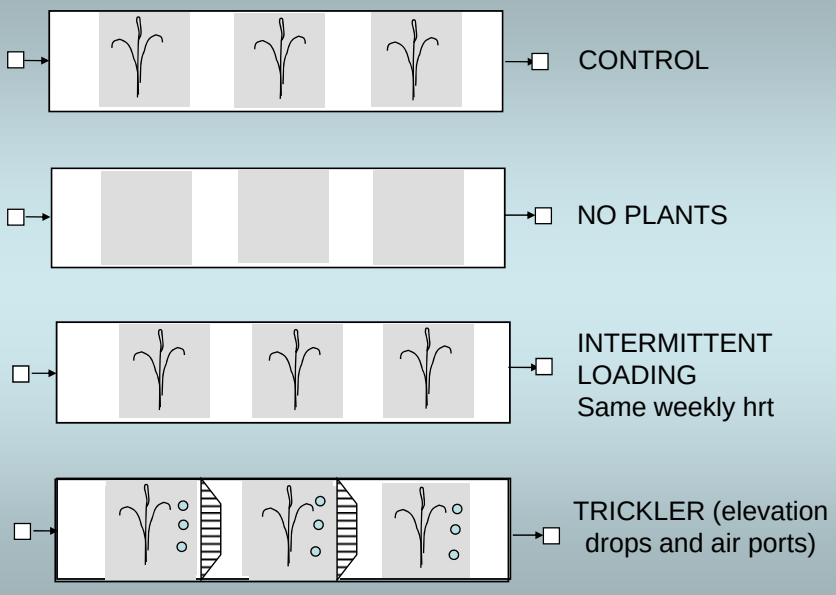
Improving Ammonia and Phosphorus Removal in SSF Wetlands

funded by Texas Onsite Wastewater Treatment Research Council

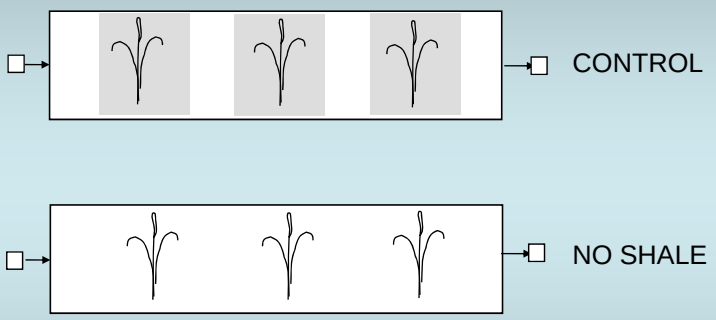
(1) Passive techniques to enhance aeration (and nitrification)

(2) Special substrate to enhance P sorption

NITROGEN REMOVAL MINI-WETLANDS



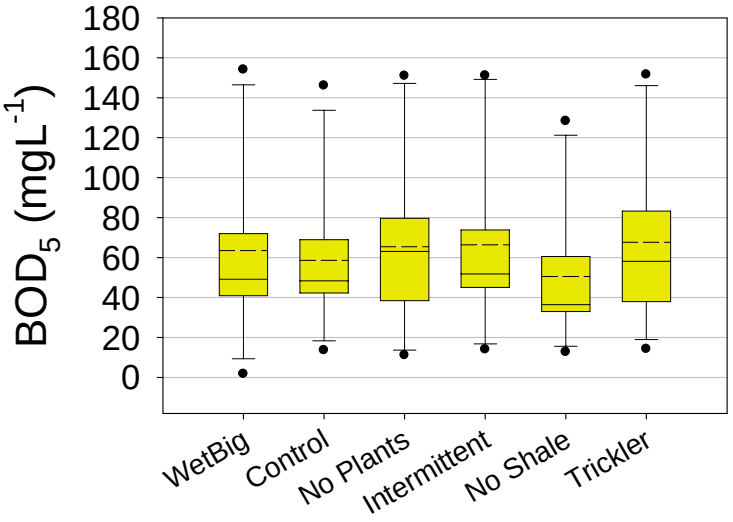
PHOSPHORUS REMOVAL MINI-WETLANDS



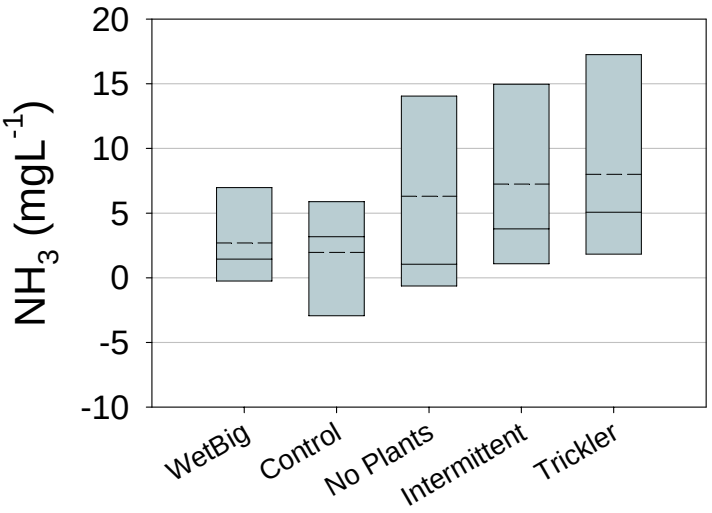
Design Features

- Dimensions are 2 ft x 10.5 ft x 1.25 ft
- Hydraulic loading = 20 gpd/cell (1 gal per sq ft per day) slightly less than big wetland
- HRT is approximately ~2.5 days
- Intermittent wetland has same weekly HRT
- Substrate is gravel (grade #3 concrete rock) and expanded light weight aggregate

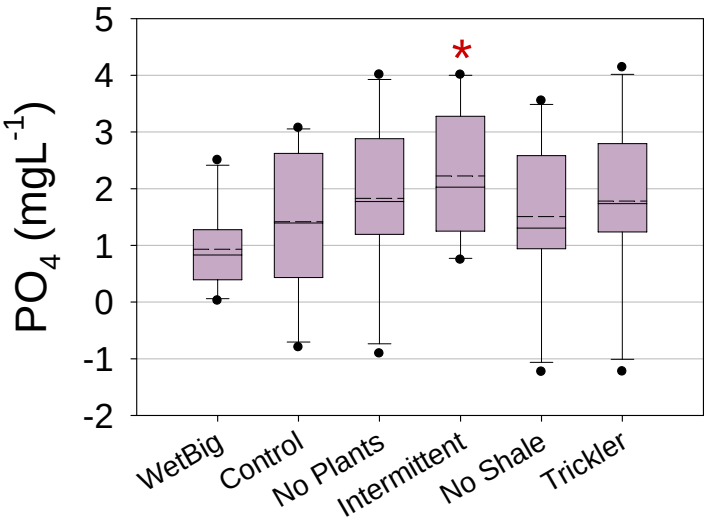
Improvement in $CBOD_5$ Concentrations
Big Wetland and Mini-Wetlands

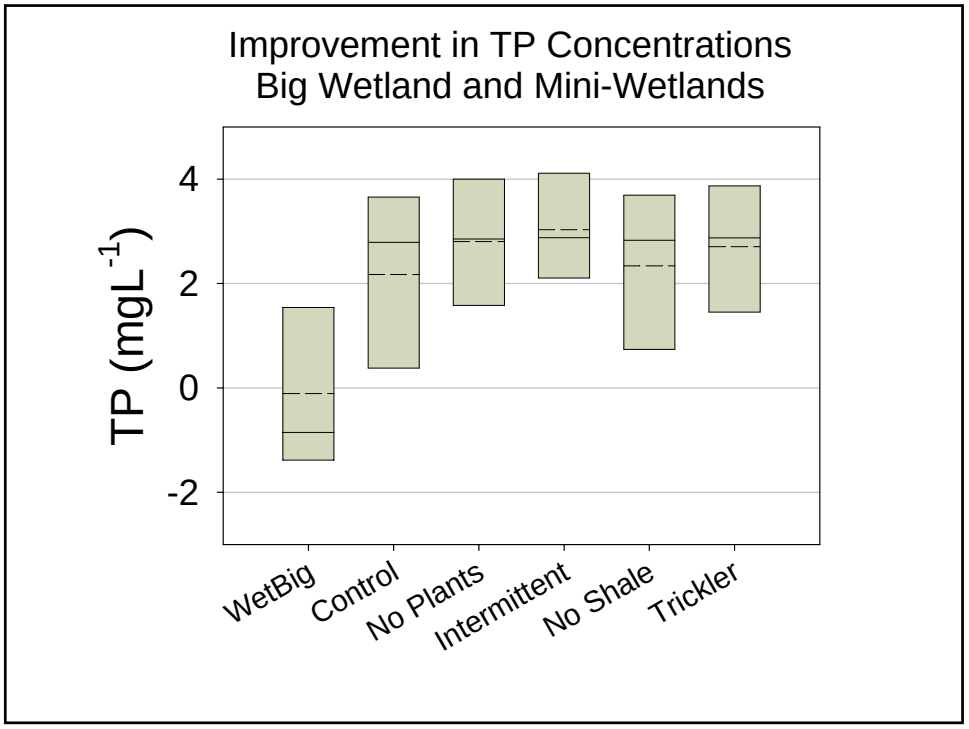


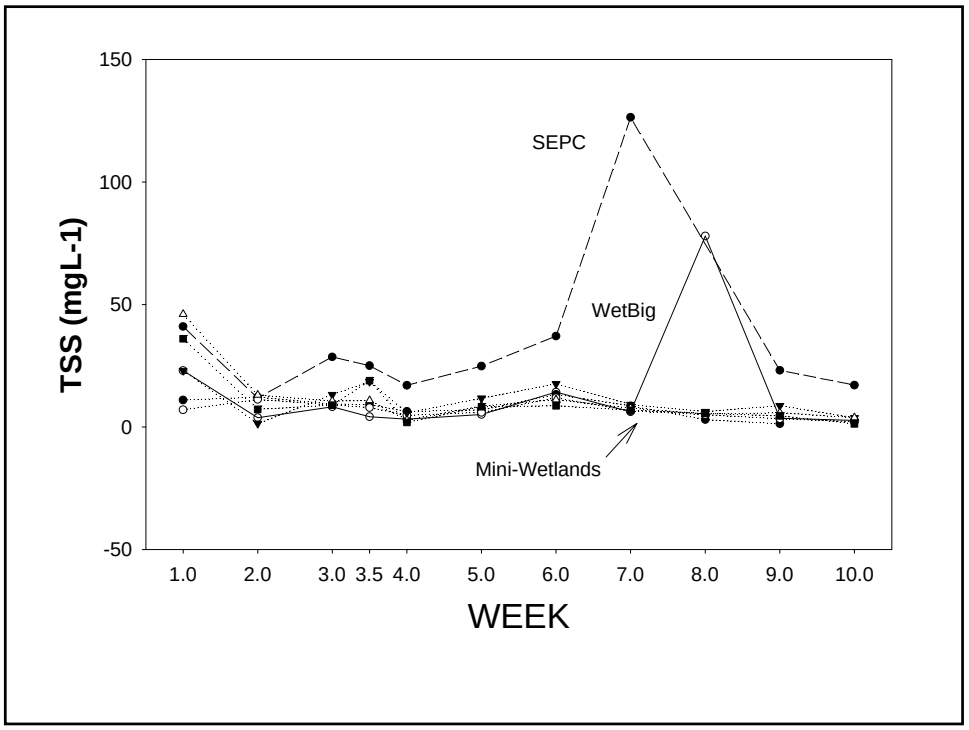
Improvement in NH_3-N Concentrations
Mini-Wetlands



Improvement in PO_4-P Concentrations
Mini-Wetlands




Improvement in TP Concentrations
Big Wetland and Mini-Wetlands
TP (mgL-1)
4
2
0
-2
WetBig
Control
No Plants
Intermittent
No Shale
Trickler


TSS (mgL-1)
150
100
50
0
-50
SEPC
WetBig
Mini-Wetlands
1.0
2.0
3.0
3.5
4.0
5.0
6.0
7.0
8.0
9.0
10.0
WEEK

Questions?

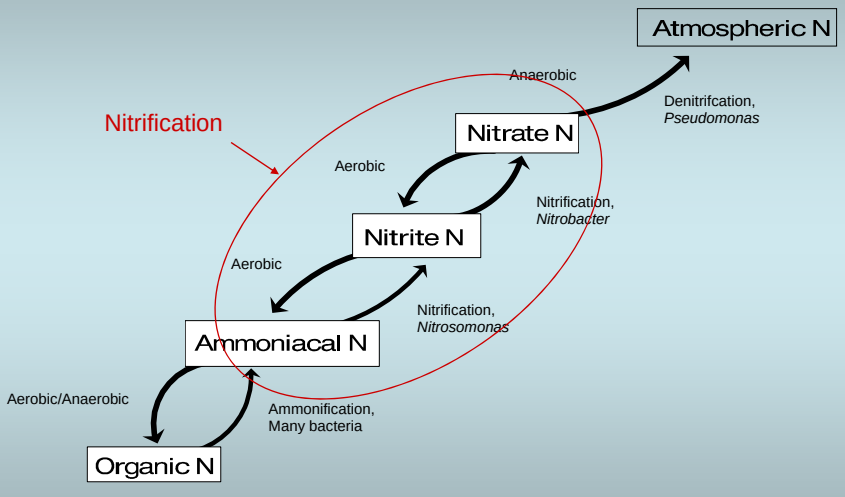
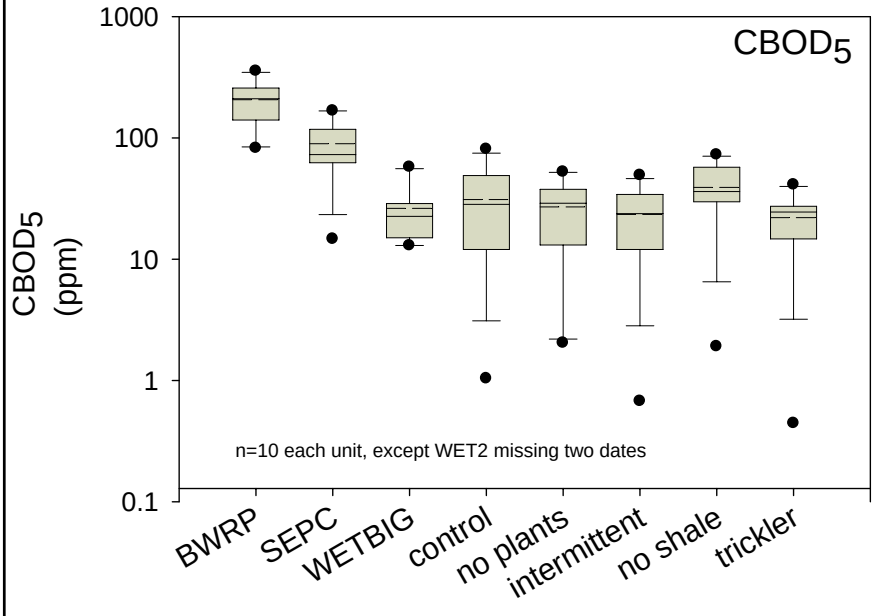
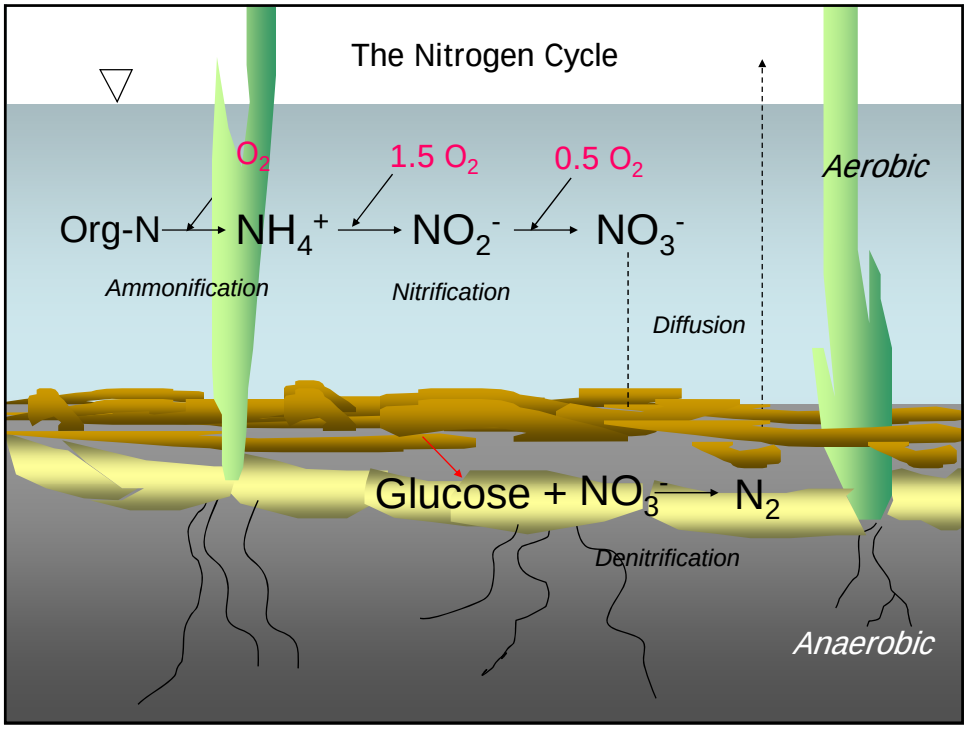


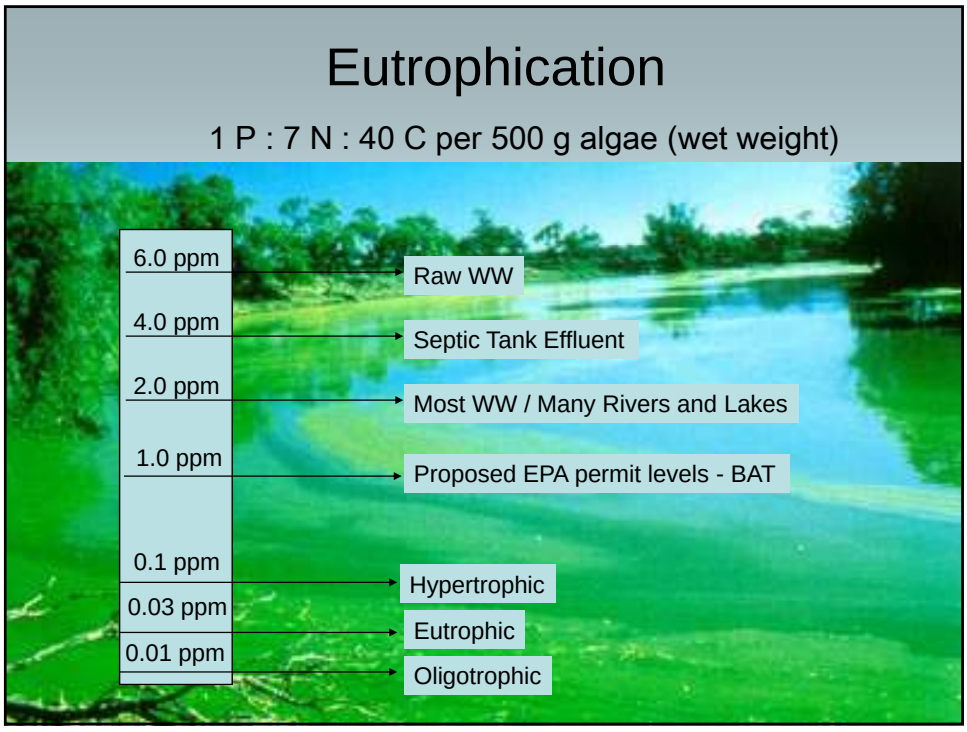
Figure from http://www.civl.port.ac.uk/enviro/env%20eng/BIOL02.DOC, John Williams

Hypotheses

- Hyp.1 Plants increase ammonia removal
  - (COMPARE NO-PLANTS to CONTROL)
- Hyp.2 Intermittent loading increase ammonia removal
  - (COMPARE INTERMITTENT to CONTROL)
- Hyp.1 Elevation drops and air ports increase ammonia removal
  - (COMPARE TRICKLER to CONTROL)




The Nitrogen Cycle
O_2
1.5 O_2
0.5 O_2
Aerobic
Org-N
NH_4^+
NO_2^-
NO_3^-
Ammonification
Nitrification
Diffusion
Glucose + NO_3^-
N_2
Denitrification
Anaerobic


Eutrophication
1 P : 7 N : 40 C per 500 g algae (wet weight)
6.0 ppm
Raw WW
4.0 ppm
Septic Tank Effluent
2.0 ppm
Most WW / Many Rivers and Lakes
1.0 ppm
Proposed EPA permit levels - BAT
0.1 ppm
Hypertrophic
0.03 ppm
Eutrophic
0.01 ppm
Oligotrophic